N080-630 ERIC REPORT RESUME

ED 010 081 10-06-66 24 (REV)

AN EXPERIMENTAL STUDY IN THE USE OF PROGRAMED MATERIALS FOR SEVENTH-GRADE OPEN-ENDED LABORATORY EXPERIENCES.

CARNES, PHYLLIS E.
FDX17906 UNIVERSITY OF GEORGIA, ATHENS

BR-5-8088
 - -66
EDRS PRICE MF-$0.36 HC-$8.48 227P.

*GENERAL SCIENCE, *PROGRAMED INSTRUCTION, *SCIENCE LABORATORY, *PROBLEM SOLVING, *EFFECTIVE TEACHING, INSTRUCTIONAL TECHNOLOGY, SEVENTH GRADE, EDUCATIONAL EXPERIENCES, ATHENS, GEORGIA

A NONPROGRAMED METHOD FOR TEACHING SEVENTH-GRADE GENERAL SCIENCE WAS STUDIED, USING A PROBLEM-SOLVING APPROACH THROUGH SELECTED, OPEN-ENDED, LABORATORY EXPERIENCES. PARTICULAR REFERENCE WAS GIVEN TO ANY STUDENT CHANGES IN (1) FACTUAL GAINS, (2) SUBJECT-MATTER COMPETENCY, (3) COMPREHENSION OF SCIENTIFIC CONCEPTS, PRINCIPLES, AND GENERALIZATIONS, AND (4) SCIENTIFIC INTERESTS. THE STUDENT SAMPLE WAS ASSIGNED TO FOUR ACADEMIC TEAMS OF FOUR TEACHERS EACH IN THE RESPECTIVE AREAS OF ENGLISH, MATHEMATICS, HISTORY, AND SCIENCE. THIS TEAM-STUDENT POPULATION WAS DIVIDED INTO 4 SECTIONS, WITH EACH SECTION HAVING APPROXIMATELY 30 STUDENTS, THUS PROVIDING 2 EXPERIMENTAL AND 2 CONTROL STUDY GROUPS. THE PROGRAM DEVELOPED FOR THE STUDY CONTAINED IN ITS FINAL VERSION 6 LESSONS OF AN INTERDISCIPLINARY NATURE TOTALING 590 LINEAR FRAMES. DATA WERE OBTAINED FROM THE FOLLOWING SOURCES (1) ACADEMIC AND GUIDANCE RECORDS, (2) RESULTS FROM A GENERAL INTEREST SURVEY AND UNIT PRE-AND POST-TESTS, (3) RESULTS FROM AN EVALUATIVE QUESTIONNAIRE, AND (4) RECORDS OF NUMBER OF FRAMES MISSED IN EACH PROGRAMED LESSON. THE OPEN-ENDED, PROBLEM-SOLVING ASPECT OF THE PROGRAM WAS USED WITH BOTH EXPERIMENTAL AND CONTROL GROUPS. ONLY THE EXPERIMENTAL GROUPS, HOWEVER, RECEIVED PROGRAMED INSTRUCTION. IN THE END THE ACHIEVEMENT OF THE CONTROL GROUPS, AS MEASURED BY THE FACTUAL, CONCEPTUAL, AND TOTAL POST-TEST SCORES, WAS SIGNIFICANTLY HIGHER THAN THAT OF THE EXPERIMENTAL GROUPS. THUS, THE NONPROGRAMED METHOD APPEARED THE BETTER FOR INSTRUCTIONAL PURPOSES. A NUMBER OF OTHER AREAS WERE SUGGESTED FOR ADDITIONAL RESEARCH IN THE FIELDS OF GENERAL SCIENCE AND PROGRAMED INSTRUCTION BASED UPON THE RESULTS. (JH)

AN EXPERIMENTAL STUDY IN THE USE OF PROGRAMMED MATERIALS FOR SEVENTH-GRADE OPEN-ENDED LABORATORY EXPERIENCES

by

PHYLLIS EILEEN CARNES

University of Georgia

Athens, Georgia 30601

1966

The research reported herein was supported by the Cooperative Research Program of the Office of Education, U.S. Department of Health, Education, and Welfare.

TABLE OF CONTENTS

Chapter | | Page

LIST OF TABLES

CHAPTER I

THE PROBLEM AND DEFINITION OF TERMS

Statement of the Problem

The purpose of this study was to ascertain the effectiveness of a non-programmed, problem-solving method of teaching seventh-grade general science and that of a programmed, problem-solving approach through selected, open-ended, laboratory experiences.

An environment for personal inquiry is being seen as a fundamental characteristic of the science program at all levels. Inquiry is broadly defined as a search for truth, information, or knowledge. Teaching science as inquiry should show students how knowledge arises from the interpretation of data, that the interpretation of data proceeds on the basis of concepts and assumptions that change as our knowledge grows. Because these principles and concepts change, knowledge changes also inasmuch as we know more, and better, than we did before. The student should build up his store of knowledge in connection with the laboratory experience, rather than go through the laboratory experience merely to illustrate and clarify the knowledge which he has acquired elsewhere.

Objectives

The specific objectives are listed below:

1. To compare the data for any significant gains in factual, subject-matter competency as measured by the factual-

oriented posttest.

2. To compare the da'a for any significant gain in the comprehension of scientific concepts, principles, and generalizations as measured by the conceptual-oriented posttest.
3. To determine the difference between the mean achievement of students using programmed materials and the mean achievement of students using the non-programmed approach as measured by the total posttest.
4. To ascertain if there are differences between the effects of the two approaches concerning development of interest in science as measured by the <u>Kuder General Interest Survey</u> (Form E).

Hypotheses

This experiment was based upon the substantive hypothesis that desirable change is brought about by the experimental treatment. Therefore, the substantive or research hypothesis that the experimental treatment will yield significant gain differences for the experimental groups, as measured by the posttest, is stated. In order to test a substantive hypothesis, however, it is necessary to present an operational hypothesis or hypotheses in quantitative and statistical terms. The following operational hypotheses were tested in the null form:

1. There is no significant difference in factual, science subject-matter competency between the control groups and

experimental groups as measured by the factual-oriented posttest.

2. There is no significant difference in the comprehension of scientific concepts, principles, and generalizations for students taught by the programmed, laboratory approach as compared with the gain for students taught by the non-programmed technique as measured by the conceptual-oriented posttest.
3. There is no significant difference between the mean achievement of students using programmed general science materials, and the mean achievement of students using the non-programmed approach as measured by the total unit posttest.
4. There is no significant difference concerning development of interest in science for the students in the experimental group as compared with students taught by the non-programmed method as measured by the Kuder General Interest Survey (Form E).

Definition of Terms

For the purpose of this study, the terms listed below have the following meanings:

Concept—an idea including many separate percepts; a mental image of an event, a quality, or a quantity.

Generalization—the application of a general concept to a relatively new object or situation; process whereby

one reaches a judgment applicable to a whole class often on the basis of experience with a limited number of the class.

Interest—an individual's preference for an activity in reference to his degree of liking for alternate activities as measured by a standardized inventory such as the Kuder General Interest Survey (Form E).

Scientific Interest—when capitalized, refers to the Scientific scale of the Kuder General Interest Survey (Form E) or the student's score on this scale.

Science achievement—the number of correct responses on a test designed to assess the subject's understanding of the science subject matter, and the concepts, principles, and generalizations relevant to the respective curriculum pertaining to this study.

Intelligence Quotient—the deviation I.Q. taken from published norms of the California Short-Form Test of Mental Maturity, Junior High Level.

Reading level—raw score values for both reading vocabulary and reading comprehension as assessed by the California Achievement Tests, Junior High Level.

Science average—a value derived by assigning number values to the five-letter grading scale as follows: A = 4; B = 3; C = 2; D = 1; F = 0. For this study the science average was obtained from the two quarters of the

seventh grade of the current academic year, 1965-1966.

Low ability level—the I.Q. range from 75-89 of the population under study as measured by the California Short-Form Test of Mental Maturity, Junior High Level.

Low average ability level—the I.Q. range from 90-104 of the population under study as measured by the California Short-Form Test of Mental Maturity, Junior High Level.

High average ability level—the I.Q. range from 105-119 of the population under study as measured by the California Short-Form Test of Mental Maturity, Junior High Level.

High ability level—the I.Q. range from 120 up of the population under study as measured by the California Short-Form Test of Mental Maturity, Junior High Level.

Stimulus—statement, rule, principle, or example presented in a manner designed to evoke a specific response from a subject.

Response—reply or reaction by a subject to a stimulus.

Frame—a unit in a programmed sequence arranged in a particular pattern of stimulus, response, and reinforcement.

Programmed instruction—learning content arranged in frames and presented in a sequence designed to elicit specific responses, followed by immediate reinforcement.

Linear program—program in which learning content is divided into small increments so arranged that there is

minimal possibility of subject errors.

Problem-solving approach—an orderly method of applying inductive and deductive methods of reasoning to perplexing, open-ended, laboratory experiences.

Open-ended experiences—the open-endedness and inquiry value of these experiences appear mainly in the form of the questions that are asked in the body of the directions. These questions lie at four levels: (a) those which can be answered from the experience at hand, (b) those which can be answered only after considerable investigation and thinking, (c) those which cannot be answered with certainty by the student or anyone else, (d) those which probably cannot be answered at all with our present state of knowledge. Also under further investigations suggested at the end of each of the programmed lessons, the experience is open-ended in that the student may apply, indefinitely, the principles learned to extensions of the same idea.

Non-programmed method—a method whereby students are taught by a problem-solving, lecture-demonstration technique.

Programmed method—a method whereby students are instructed by means of a programmed, problem-solving, open-ended, laboratory approach.

Treatment—administration of the programmed sequence or the non-programmed instructional procedures.

<u>Factual-oriented test</u>—a test with items designed for recall of facts.

<u>Conceptual-oriented test</u>—test items designed for measuring a student's knowledge of certain concepts, and their ability to apply concepts to a relatively new situation.

<u>Total unit test</u>—the combined factual-oriented and conceptual-oriented test items.

Basic Assumptions

This study is dependent upon the following basic assumptions:

1. That the *California Short-Form Test of Mental Maturity, Junior High Level* provides reasonably valid measures of the student's language ability and non-language ability.
2. That the personal information provided by the student's permanent record folder is correct.
3. That student responses to an evaluative questionnaire are valid indications of their likes and dislikes concerning programmed materials.
4. That the students' science teachers' assessment of their performance, in the former quarters of the seventh grade, is a valid indication of their performance level in science.

Significance of the Study

In teaching science, a continuing area of concern to educators has been the problem of integrating laboratory experimentation with

scientific theory. The need to individualize course content for students is also recognized. Programmed instruction may offer one solution to both these difficulties. If the science curriculum can be programmed so that individual rates of learning can be dealt with more effectively, and if laboratory materials can be developed which enable students to conduct experiments efficiently on an individualized basis, laboratory experimentation will be integrated more satisfactorily into the typical science course. What is generally considered an advantage of programmed instruction is the systematic, controlled, and sequential fashion in which content is presented to the learner. In programmed instruction provision can be made for differentiating instruction to accommodate individual differences (Fry, 1959; Stolurow, 1961; Travers, 1945). It is the consensus of science educators that laboratory exercises must be incorporated into the programmed sequence in order to receive full benefit of those advantages in science courses.

A survey of the subject areas in which programmed instruction has been used reveals that those areas which require laboratory-like activities are rare (Hanson, 1963). To the writer's knowledge, this investigation should be unique in that no programmed, open-ended, laboratory experiments on the junior high level have been developed and tested previously. The conclusions from this study should aid in evaluating the future program of seventh-grade science instruction, and; concomitantly, should demonstrate what programmed, problem-solving, open-ended, laboratory experiences could contribute, if any contribution,

to the whole spectrum of science disciplines.

A student's laboratory exercises should constitute experiences which serve to help him discover and explore the principles being studied. This study seeks to obtain evidence relevant to this problem by investigating the results of using instructional materials which were designed to be an exploratory experience dealing with problems real to students.

The results of studies of programmed materials in general are somewhat contradictory. The findings of this study will provide additional insight into the effectiveness of programmed materials as an instructional method.

The results of this study should be of value to educators who are concerned with individualized instruction for upper elementary and/or junior high school students.

Limitations of the Study

Some limitations of this study are:

1. The subjects included in the study were limited to those students drawn from the seventh-grade population of the Clarke County School System, Athens, Georgia, for the academic year, 1965-1966.
2. The study was limited to a total population of 221 students. The four sections of experimental groups numbered 106. The four sections of control groups numbered 115.
3. Due to the absences of the subjects on testing days,

incomplete data from cumulative records, or a student's failing to finish the experimental lessons, some students were of necessity dropped from the study.

4. For administrative reasons, intact classes of seventh graders had to be used for this study with the result that groups could not be matched or randomly assigned at the beginning of the study. However, the statistical model used compensated for original differences in the groups in achievement and intelligence.
5. As has been cited by many investigators employing the experimental group-control, group design in research, the Hawthorne effect was potentially a contaminating factor. The achievement of students who were in an experimental group was affected by the mere fact that they were members of an experimental group. It was also likely that members of the control groups were aware of the experimental nature of the study. The exact effects of these realizations can not be isolated, but the existence of these effects must be recognized.
6. The only measure of student understanding of science in this study was the posttest instrument designed by the investigator.

Organization of the Remainder of the Study

This chapter has presented a statement of the problem, its

objectives, hypotheses, definitions of terms, basic assumptions, and limitations.

The second chapter presents a review of related research, which includes a review of the development of programmed instruction, studies dealing with programmed material, reviews of programmed science materials, and research dealing with programmed laboratory experiences. The third chapter gives descriptions of the subjects, the experimental design, the program, description of the treatments, administration and duration of the experiment, sources and types of data, a description of the testing instruments, and the types of statistical analyses used.

The fourth chapter presents results of the study; the fifth chapter includes a discussion of findings and conclusions. A summary and implications for further research are contained in the sixth chapter.

CHAPTER II

REVIEW OF RELATED LITERATURE

Shortly after this century passed the half-way mark, followers of educational research and industrial training began to observe the emergence of a new method of learning. Actually, it was not new; it had its beginning even in the days of Plato and Socrates—and perhaps before. Attention was being drawn by the novelty of this method inasmuch as it was diametrically opposed to the group lecture method monopolizing the classroom of the twentieth century. This method was programmed learning, regarded as a recent development because its practical application to education has become apparent only in the past few years.

Because of its recency in entering the educational stage, the literature related to the development of programming is herein reviewed as a general background for this study, as well as its implementation, developments concerning instruction in the sciences, and research related to programmed laboratory experiences. The first section presents a summary of the development of programming. The second section presents a review of research of programmed instruction as an educational medium. The third section consists of reviews of programmed science materials; the fourth encompasses the available literature related to programmed laboratory experiences.

The Development of Programmed Instruction

One of the earliest programmers was Socrates, who developed a

program for geometry, which was recorded by Plato in the dialogue, Meno. It was Socrates' method to guide his followers to knowledge by conducting them conversationally along a path from fact to fact and insight to insight. His method could merit being termed "oral programming" which Banks (1963) has employed at the United States Air Force Academy in a course in aerodynamics using closed-circuit television. Each student has a switch which he uses to indicate his answer to key questions asked by the instructor throughout the lecture. The instructor has a device which records the number of correct answers and allows him to gauge the class's understanding of each important point. A workbook of programmed exercises follows each television presentation to reinforce the lecture.

Closer to our own times has come the tutorial method. This was perfected by the colleges of the great English universities and taken up by many of this country's colleges in one form or another. The continuous exchange of questions and answers between the tutor and his student, the unfolding of information and explanations, and the constant selection of new materials on the basis of the student's mastery of what has gone before is indeed a forerunner of programmed instruction.

The antecedents of current programming practices are many; however, the method as it is now employed may be considered to derive from dynamic efforts begun in the 1920's (Lysaught and Williams, 1963).

In 1926 Sidney L. Pressey, an Ohio State University psychologist, made public his pioneer studies on the first recognized

teaching machine (Pressey, 1926). His model originally was conceived as a testing machine that presented a series of questions to a student and informed him immediately whether his reply was right or wrong. The machine was essentially a box containing a revolving drum; the program was exposed through a slot in the box and the student indicated his response by pressing one of four buttons. The correct button released the drum and permitted the student to move on to the next question; an incorrect response did not release the mechanism. Pressey thought this principle to be useful; the student always found the correct answer, and as the correct answer was always the last answer given, it made the strongest impression on the student. By a simple adjustment, the machine could be used for testing; it merely progressed to the next question without regard to the student's response (Fry, 1963).

Even though Pressey's devices initially emphasized the automation of testing rather than of instruction, it was evident that they incorporated principles of learning enunciated by psychologists—the major emphases being on active participation, immediate confirmation, and individual progression adapted to the capabilities of individual learners (Hilgard, 1964).

Despite the promise of Pressey's experimental results and his interest, along with others, in encouraging further research, the movement in behalf of such devices lost its impetus. There are perhaps at least two explanations for this loss of impetus. First, no provision was made for systematic programming of materials to be used

in these machines, and second, the onset of the depression and its impact on social conditions and education apparently offered an unfavorable environment for such a revolution in the nation's schools.

By 1954, however, conditions in the world had changed. Greater knowledge in classroom behavior, especially about the analysis of learning behavior, and a demand for education on an unprecedented scale, created a vastly different set of circumstances. In this fresh climate, two Harvard psychologists, B. F. Skinner and James G. Holland, devised auto-instructional methods which have served the current generation as the bases for its own excursions into programmed learning.

Skinner proposes that reinforcement is one of the essential processes in an instructional program. There is acknowledgment or reward of some kind to show that an organism has performed to satisfaction. Reinforcement theories have sprung from laboratory observation and analysis of the learning behaviors of lower organisms. However, a projection of their conclusions to human beings provides new insight into the educational problems of teachers and psychologists alike.

Considerations of Skinner supplied the ingredient missing from Pressey's experiments. It provided the idea of programming instructional materials that Pressey's machines needed. This theory has the further merit of complementing a body of educational beliefs long utilized in classroom teaching. The idea of reinforcement provides a rationale for believing that a complex body of learning

can be separated into its smallest components. In any case, programmed learning does not break completely from previous methods of teaching.

Historically, the term "program", as applied to a sequence of instruction presented by a teaching machine, derives from the 1954 paper of Skinner, whose influence has guided the mainstream of developments in programmed instruction during the 1950's and 1960's (Skinner, 1954).

Hilgard (1964) has defined a "program" as follows: An instructional program is a vehicle which generates an essentially reproducible sequence of instructional events and accepts responsibility for efficiently accomplishing a specified change from a given range of initial competencies or behavioral tendencies. This definition can encompass most of the forms of programs that have been proposed. It makes no particular theoretical presuppositions and does not require individual progress or overt response by the learner as part of the definition. The definition does imply a programmed sequence of learner behavior, not merely a reproducible set of stimulus materials.

The linear, or extrinsic, programs present a sequential development of the material through which each student, regardless of his response, proceeds in exactly the same order. The student responds to the first item, and then, to the second item. He goes on to the third and subsequent items in linear form irrespective of any errors he might make on intervening items.

The constructed-response program is associated chiefly with

the work of psychologist B. F. Skinner and his associates, including James Holland. They believe that the absence of errors contributes to more efficient learning, as a correct answer is in effect a "reward" or "reinforcement" for the student; that is, knowledge that he has answered correctly is stimulating and rewarding to the student, and an incentive to greater effort or continued effort.

The second basic type of program is the so-called branching or intrinsic program developed by Crowder (1959). In the branching program, the student is presented with a problem and with several alternative answers, one of which is correct. When the student chooses an answer he is instructed to move to a specified frame. This frame then tells him if his answer was incorrect and explains why it was incorrect. The frame then may return the student to the original item which he had answered incorrectly for another trial, or it may direct him through a subprogram—further instructing him in the basic knowledge presumed to be necessary for the item he had answered incorrectly. In either case, the student is eventually returned to the missed item which he then, presumably, answers correctly. If he again chooses an incorrect alternative, a similar process is followed. Ultimately, he is returned to the missed item and answers it correctly. He is then directed to the next frame in the program where the same process may be repeated should he answer that item incorrectly.

Branching programs are published in the form of scrambled textbooks when the publication is in the form of a book. The scrambled

textbook arranges the frames and alternative answers to frames in such a way that the student is directed to search through the book to proceed to the next step. It does not move sequentially, page by page, as does the linear program (Green, 1963).

Research Related to Programmed Material

Literature referred to in this section is representative of investigations related to programmed material.

Coulson and Silberman (1960) gave branching and linear programs to junior college students and found the linear, constructed-response group had a higher mean score on the constructed-response section of the test, but there was no difference on the multiple-choice test.

Fry (1960) used a linear program with either multiple-choice or constructed responses to teach Spanish words and phrases to ninth-grade pupils. The criterion test consisted of both types of items. The conclusion reached from the data was that the constructed-response method was superior for recall.

Larkin (1964) experimented with sixty children aged fourteen years in using programs. No significant difference was found between linear and branching methods of an immediate posttest consisting of both composed and recognition items. Separate analyses of each section of the test found neither program superior for recall or for recognition. In addition there were no significant differences between ability levels on either part of the test even though average I.Q.s for the extreme groups differed by twenty points. Sixteen

weeks later the same test was administered again. Analysis of the full test scores showed no advantage to either method of programming; ability levels, were, however, significantly different on this occasion.

In a second study, Larkin and Keith (1964), experimented to ascertain whether younger pupils learn better from a linear, constructed-response program or from a branching, multiple-choice program. It was predicted that less mature pupils would learn and retain more after using the constructed-response program. This hypothesis was confirmed. Analysis of variance indicated that the methods were significantly different. The significant ability-by-method interaction showed that the branching program is less effective with the lower ability groups.

Analyses of the scores on the constructed-response and also on the multiple-choice items were carried out. Thus the conclusions of Fry, Coulson, and Silberman, referred to earlier, that a constructed-response method results in higher scores on a constructed-response test than does a multiple-choice method were confirmed.

Keislar (1959) investigated the relationship between intelligence and programmed materials, correlating mental age with student achievement in a linear program. The course content was based on elementary concepts concerning rectangles. Fourteen experimental subjects were selected from fifth and sixth grades and matched for intelligence, sex, reading ability, and pretest scores. The rank order correlation coefficient among the variables was reported as

modest.

Shay (1961) examined the relationship of intelligence, in respect to the probability of obtaining a correct response, to achievement. Ninety subjects were selected from the fourth grade on the basis of scores on a group intelligence test and assigned to three groups: above average, average, and below average. The programmed content was a fourth-grade unit in Roman numerals. The results of Shay's study indicate that differences in achievement occurred consistently among the three intelligence groups, with the above average group achieving at the higher level and the below average group achieving at the lowest level.

McNeil and Keislar (1961) examined the relationships of sex and intelligence on achievement in programmed instruction. Sex differences were reported in favor of boys. The correlations of intelligence and achievement ranged from 0.40 to 0.89.

A positive relationship between intelligence and mathematics achievement was reported by Andrews (1963) utilizing programmed instruction with elementary school age subjects. Andrews found that girls consistently exceeded boys in achievement during programmed instruction.

Research Related to Programmed Science Material

Pollard (1964) using a card deck unit in biology in his general science classes, reported that when two groups of students, one using the card deck and the other exposed to conventional methods,

were tested, there was a significant difference in favor of the experimental group. Scores showed a difference of 11.5 points, with the experimental group having a mean 15.8 percent higher than the mean of the control group.

Wong (1964), on the secondary level, described the processes in producing three units in a biology class, but no data were reported as to their implementation.

On the college level, Lawson (1960) presented data on a one-week, scrambled-book, genetics unit. The sample consisted of ten sections of students registered for a natural science course. Half the sections were used as an experimental group and the other half as a control. A thirty-item objective test was administered which was designed to measure the transfer of reasoning analysis and application. The means and standard deviations of the scores were determined for each group with t-test treatment. Results indicated the difference in performance was significant beyond the 0.01 level in favor of the experimental group.

Reush and Cornell (1963) tested an edition of a program on molecular equilibrium. The program was finished in a time range of from three to twelve hours, with an average of six hours, by 300 college chemistry students in a general college chemistry course. The investigators reported an increase in grade average as a result of the programmed materials.

Research Related to Programmed Laboratory Experiences

Wash (1964) conducted an experiment in the use of programmed

materials in teaching high school chemistry. Investigation relative to difference in chemistry achievement between the control and experimental group, the variability in time spent in the instructional program, and the administrative feasibility of secondary students to conduct individual experiments as a regular part of the programmed sequence was performed. The investigator reported that students can achieve at significantly higher levels through the use of a programmed chemistry sequence which includes laboratory exercises, and that there is a positive relationship between time in the programmed sequence and achievement. Also concluded was that the use of programmed instruction in laboratory science courses is feasible and presents no unusual administrative problems.

A three-phase study has been completed and reported by Hedges and MacDougall (1965) regarding the teaching of fourth-grade science by means of programmed science materials with laboratory experiences. In the first phase of the investigation, a pilot study, the achievement of those students using programmed materials during the investigation was significantly higher at the 0.05 probability level than the achievement of those who were taught by more conventional methods.

The primary purpose of Phase II was to write and refine through field testing and analysis, a complete course of science study for the fourth grade, using Skinner's small-step approach. A year-long use of these programmed materials revealed no significant differences in achievement.

The efficacy of the programmed learning approach was investi-

gated in a more controlled situation, described by Phase III. Nineteen fourth-grade classes were randomly assigned to each of three treatment groups. The first group of six classes of students studied science for one semester using the programmed materials with each child doing the experiments. The second group of six classes of students studied science for one semester by means of the programmed materials coupled with the students only reading about the experiments; the third group of seven classes of students studied by means of the programmed materials rewritten in textbook form with fixed assignments by the teacher and teacher-demonstration of the experiments in the emulation of the conventional approach to science teaching. The three groups were compared on the instructional effectiveness of the method of science instruction, where instructional effectiveness was defined as (a) achievement, (b) interest and attitude, (c) value of laboratory experiences, and (d) retention. The results of the post-experimental testing revealed no significant mean differences were found among the three treatments in initial intelligence and science achievement, final measures of science achievement, level of interest in science, and measures of retention.

A bulletin has been published by the Michigan Department of Public Instruction (Michigan, 1965) presenting open-ended, laboratory-centered, science experiences for grades seven, eight, and nine, but the literature reveals no published research involving the use of these experiences. The Committee on Science responsible for these laboratory-experience outlines believe that it is possible to select

ideas or understandings of an interdisciplinary nature, which can be introduced at the junior high school level or lower, and which will continue to be valid in progressively more sophisticated fashion at each succeeding level to graduate school and beyond.

A subcommittee, chaired by Professor W. C. Van Deventer, Professor of Biology, Western Michigan University, is responsible for having implemented a few ideas of the type indicated. The work is an on-going project; presently over twenty laboratory-experience outlines have been completed.

There is reported in the literature, research completed under the auspices of the Department of Defense, U.S. Air Force, certain laboratory-like activities. Some American industries have had under study, programming of certain mechanical procedures.

Cohen and Fetterolf (1963) developed an adaptation of programmed instruction for a laboratory course in qualitative analysis. Theory is given in lecture but the twenty-four laboratory hours are structured so that after necessary experimentation, confirmation of the students' answers is given by a programmed guide. No attempt has been made to evaluate results by statistical analysis.

No other reported researches in the area of programmed laboratory instruction were discovered by the investigator.

This chapter has summarized the development of programming, research related to developments of programmed instruction in the sciences, and research relevant to programmed laboratory experiences.

The development of programming dates back to the teaching

method used by Socrates. The continuous exchange of questions and answers under the tutorial method is a forerunner of programmed instruction. Efforts by S. L. Pressey in the 1920's were probably the beginning of the method of programming as it is now employed. B. F. Skinner and J. C. Holland devised auto-instructional methods which have served the current generation as to the bases for its excursions into programmed learning. Linear and branching techniques are the two basic types of programming.

In the studies cited the linear or constructed-response technique was superior for recall with the exception of the study by Larkin (1964) in which it was reported that neither the linear nor the branching method was superior. Intelligence was found to be related to achievement in programmed instruction. The findings concerning the relationship of sex to achievement in programmed instruction tend to favor the boys. Data reported for studies which were related to programmed science material showed significant achievement differences in favor of the experimental groups.

Few research projects involving programmed laboratory science experiences were found. Among those cited, only two reported data analyses. One investigation revealed a significant difference in achievement favoring the experimental group. The other study reported no significant differences were found in achievement or level of interest in science.

In the following chapter the procedure for implementing the research project is discussed. Descriptions are given of the

experimental design, the subjects, the program, the treatments, the sources and types of data, the testing instruments, and the types of statistical analyses used.

CHAPTER III

PROCEDURE

Experimental Design

For the purpose and objectives of this study, research design number 10 proposed by Campbell and Stanley (1963) was considered appropriate, since the groups constitute naturally assembled collectives. The investigator did not control the selection of the subjects, but in the use of this design it is assumed that the experimental treatment can be assigned randomly to the groups.

Table 1, page 28, depicts the research design incorporated by the investigator.

The experimental schedule followed in executing the research plan may be found in Appendix D.

Subjects

The subjects in this study were samples of the population of students enrolled in the seventh grade of the Clarke County High School during the academic year, 1965-1966. The total seventh-grade population was assigned to four academic teams of teachers. Each team consisted of four teachers who instructed students in respective areas of English, mathematics, history, or science. The team-student population was divided into four sections, with each section consisting of approximately 30 students. The investigator used subjects from two academic teams, one population with N = 118, and the other with N = 103. A total of eight sections were involved with N = 221.

Table 1

Research Design

Subjects	Main Effects				Interaction of Main Effects				Covariates							Criterion
	Treatment T_1 T_2	Teacher t_1 t_2	Sex M F	Ability Level 1 2 3 4	Sex by Level	Sex by Treatment	Treatment by Level	Treatment by Teacher	Age	RV	RC	L	NL	Sci Avg	Pre-Test	Post Test
Control																
Experimental																

T_1 = Treatment one or Experimental Group
T_2 = Treatment two or Control Group
t_1 = Teacher one
t_2 = Teacher two

RV = Reading Vocabulary
RC = Reading Comprehension
L = Language intelligence
NL = Non-language intelligence
Sci Avg = Science Average

Two science teachers from two academic teams participated in this study. Both cooperating teachers instructed two experimental and two control groups.

The Progr m

A programmed unit in seventh-grade science of an interdisciplinary nature was developed by the investigator. The investigator secured permission from Professor Van Deventer, chairman of the Michigan Subcommittee on Science which published a bulletin of open-ended, laboratory experience-outlines referred to earlier (Michigan, 1965), to use a selected number of the outlines. These outlines served as the framework for the programmed sequence of instructional material. Six outlines were selected under three main ideas. Listed below are the three main ideas and the titles of the six laboratory-experience outlines:

1. The idea of gradients: there are no sharp boundary lines in nature.
   a. A Gradient: The Effect of pH on Yeast Activity.
   b. A Gradient for the Separation of Chemical Substances: Paper Chromatography.
2. The idea of normal curves: related phenomena tend to vary in pattern fashion around a norm.
   a. Normal Distribution Curves Describe Variation in Nature.
   b. The Use of Normal Curves in Distinguishing Species.
3. The idea of measurement as an expression of relationship.
   a. A Study in Measurement.

b. Measurement as an Expression of Relationship: A Simple Balance.

The programmed unit of instruction, covering the six lessons, each having the respective laboratory experiment as the core learning experience, consisted of 590 modified linear frames. A copy of these six lessons comprising the unit of instruction may be found in Appendix A. This unit of six lessons was used as the sole instructional device with the experimental group.

The linear mode of programming was modified so as to allow certain frames to become open-ended. This procedure allows students, through a series of inquiries, to gather data, interpret observations, and arrive at conclusions based on such data and observations.

The combination of laboratory instruction and a programmed sequence poses some special problems. Particularly, the concept of an immediate reinforcement becomes difficult if laboratory experiences are to be meaningful. When laboratory exercises consist of small sequential steps with frequent responses, followed by immediate feedback to the pupil, it becomes difficult to allow the student to gather evidence so that conclusions will represent insights he has reached for himself. The frames containing the laboratory exercises, while guiding the student to draw an independent conclusion, attempt to assure his reaching a reasonable conclusion based on experimental evidence.

The content of the program involved those items of information necessary to an understanding of the idea of a gradient as demonstrated in varying pH environments of yeast, or in paper chromatography; the

idea of normal curves and sampling as evidenced by variety in nature or in the overlapping characteristics of related species of elm leaves; and the idea of measurement as an expression of relationship as demonstrated by a study in measurement from a microscopic quantity to a quantity such as a portion of the school grounds, or by a simple balance which called for the student's establishing his own system of measurement. The desirability for this information was identified through pilot studies as the program was being written.

The programmed sequence was developed during the period from June, 1965 to December, 1965. During this time the individual lessons in the unit were tried with students from a selected sixth grade in Clarke County, Georgia. It was felt that the problem of difficulty level of the respective frames could be assessed more confidently if students one grade level lower than the experimental population were not handicapped in performing the laboratory experiences. Sixth-grade students of differing ability levels were used. Each of the six lessons was revised after feedback from the students involved in the pilot study.

Before the six programmed lessons were tried on the sixth-grade students, all of them were submitted to a program specialist, science educator, and a specialist in each of the six fields (e.g., a microbiologist, a chromatographer, etc.) for editing. Any suggestions for revision were followed prior to their submission to the sixth-grade students. Professor Van Deventer assisted the investigator in editing all of the six programmed lessons, the

testing instruments, and all of the materials involved in this experimentation.

After the individual pilot trials were completed, a final field trial was conducted from January 3, to January 26, 1966, at Pattie Hilsman Junior High School in Clarke County, Georgia. To eliminate possible contamination of the seventh-grade population, this school was selected because of its geographic separation from the selected school cooperating in the formal experimentation. The investigator taught an experimental group with N = 31, and a control group with N = 31 selected from the seventh grade population of Pattie Hilsman Junior High School. The pretest instrument was administered to both control and experimental subjects at the beginning of the field trial. At the end of this period, the posttest was given to both groups; an evaluation questionnaire was administered only to the experimental groups. A copy of this evaluation questionnaire may be found in Appendix B.

The purpose of this final field trial was to identify the frames in which students consistently made errors or could not supply correct responses. Also, the investigator evaluated each question posed by the students to detect any faulty frames in the preface frames or in the procedural directions given for the performance of the experiment. Four of the six lessons were revised as a result of this final field trial. Other invaluable information was gleaned from this experience which contributed to a much smoother operation once the formal experimentation was begun.

The two seventh-grade science teachers at Clarke County Junior High School, who cooperated in teaching the eight sections of experimental and control groups, reviewed the six programmed lessons and performed the laboratory experiments prior to the formal experimentation period.

The modified Dale-Chall Readability Formula was used to determine the readability level of the materials. The readability level was found to be 5.6.

Description of the Treatments

Before initiating the experiment the investigator met with the two experimental and control teachers to explain the overall project and the teacher's role in the study. In the experimental sections the teachers were instructed to use the programmed laboratory experiences for the regular instruction. The experimental subjects were free to use textbooks, periodicals, and other resource material to supplement the programmed texts; but as the unit developed, no supplementary materials were used. The two teachers were instructed not to use any materials for total classroom instruction other than the programmed, laboratory materials with the experimental subjects.

The teachers were instructed to teach the control sections in their usual manner, using the curriculum materials provided by the investigator. For the control classes the teachers were provided with the content of the programmed units and with assistance in obtaining materials and preparing demonstrations in a more conventional

approach to teaching science. Six science worksheets, with questions comparable to those posed within the six programmed lessons, were provided for the teachers. The approach was still one of group problem solving; the principal special instruction for the teaching of the control groups was that no programmed materials of any sort were to be used in their classes at any time during the term of the experiment. Also there were to be only teacher-demonstrations and no individual experiments performed by the students.

The teachers were allowed to assign the science worksheets as homework in the control groups as they saw fit. These worksheets consisted of approximately ten questions pertaining to the respective lesson at hand. The student was sent to as many as eight resource books to secure information necessary for a response to a respective question. A copy of these worksheets may be found in Appendix A.

The experimental groups received no specific homework assignments, but they were allowed to study the material at home if they so desired. The students were urged to do some studying as homework in order to allow maximum class time for the performance of the laboratory experiments.

Administration and Duration of Experiment

The formal experimentation was begun at the Clarke County Junior High School, January 28, 1966. At this time the pretesting instrument was administered to both experimental and control groups. The Kuder General Interest Survey (Form E) was also administered.

The pretesting was preceded by an orientation for both control and experimental groups, with specific instructions delivered to the experimental groups in the use of the programmed sequence, the data they were asked to record, and the laboratory procedures to be followed during the experimental period.

The experimental groups next were allowed to proceed with the programmed instruction. Where a laboratory exercise was encountered by the student, he was instructed, within the programmed lesson, to proceed to the designated location in the laboratory. Here he would find equipment and supply items numbered to correspond with the list of needed supplies in the programmed lesson. The laboratory areas were under the guidance of the instructor who supervised laboratory activities and checked the outcome of experiments.

Concomitantly, the control groups proceeded as usual with the teacher lecturing and calling for discussion when a problem needed solving. Former reference was made to the assigning of science worksheets containing questions relevant to the lesson at hand. Teacher-demonstrations were performed sometime during the time spent on a respective lesson.

The investigator observed in all the experimental groups for some time every class period. Time was also spent in the control groups by the investigator and some demonstrating was performed by the investigator in the control groups.

At the conclusion of the experimental period the posttest was administered to all eight sections. All eight sections were given

the *Kuder General Interest Survey* (Form E) as a post experience. An evaluation questionnaire was administered to the experimental groups. A copy of this questionnaire may be found in Appendix B.

With twenty school days allowed for the duration of the experiment, February 25, 1966 concluded the program.

Sources and Types of Data

The data needed were obtained from six main sources: (a) records in the Clarke County Guidance Department, (b) cumulative record cards from the principal's office, (c) the administration of the *Kuder General Interest Survey* (Form E), (d) the administration of the unit pre- and posttest, (e) the administration of the evaluative questionnaire, and (f) the record of the number of frames missed in each respective programmed lesson.

Data from the Clarke County Guidance Department

Test scores for all eight Clarke County seventh-grade classes on the *California Achievement Tests, Junior High Level* and the *California Short-Form Test of Mental Maturity, Junior High Level* for the October, 1965 testing were obtained through the Clarke County Guidance Department. Scores were obtained for each of the subjects as follows:

The Cali a Achievement Tests, Junior High Level

1. Reading vocabulary score
2. Reading comprehension score

The California Short-Form Test of Mental Maturity, Junior High Level

1. Language intelligence score
2. Non-language intelligence score

Data from Cumulative Record Cards

Age, sex, grade level, and average of previous science grades were obtained from cumulative record cards.

Administration of the Kuder General Interest Survey (Form E)

In order to document any change in scientific interest as a result of the experimental project, the Kuder General Interest Survey (Form E) was administered at the beginning of the research project and at the conclusion. Scientific Interest scores were analyzed from this inventory on the subjects.

Administration of the Unit Pre- and Posttest

A specially-prepared test was administered before the beginning of the experimental period to determine students' prior knowledge of the respective curriculum content of the experimental instructional materials. The test consisted of 50 multiple-choice items. A copy of this test may be found in Appendix B.

Both the pretest and posttest were administrations of the same test prepared by the investigator. No standardized achievement measure was available which contained a sufficient range and number of items

concerning the six selected, laboratory experiences chosen for the experimental curriculum.

Administration of an Evaluative Questionnaire

At the close of the study the classroom teachers administered an evaluative questionnaire to the experimental subjects. This questionnaire was given to attempt to evaluate the students' reactions to the programmed texts. The questionnaire was devised by the investigator after having reviewed several questionnaires used for similar purposes in other studies. The students were encouraged by the teachers and the investigator to give their honest opinions.

The two teachers were also asked to evaluate the experiment. Strengths and weaknesses of the materials were pointed out. The reactions of the teachers were comparable with the general reaction of their individual classes.

Record of Number of Frames Missed

Each student in the experimental groups was given a mimeographed form, asking for the recording of the number of each frame missed within each of the six programmed lessons. The teachers and the investigator stressed that this record in no way counted as a mark against the student, but rather that the student was furnishing the investigator with helpful evidence as to the reliability of a particular frame.

Description of the Tests

California Achievement Tests, Junior High Level

The new edition was re-standardized in 1963 to take account of faults in the 1957 norms. A sample of 341 schools in 48 states was carefully selected to insure obtaining an unbiased sample. For the junior high level, grades seven through nine, the reliability coefficients for the various tests range from 0.83 to 0.95 with a reliability coefficient for the total battery of 0.98. These coefficients were computed using the Kuder Richardson formula 21. The standard error of measurement for the raw score is 9.4 points, for grade placement, 0.2 months.

The item discrimination data are indicative of the efficient functioning of nearly all items. A high degree of concurrent validity is reflected in the high correlation of scores on the new edition and other standardized achievement tests (California Manual, 1963).

California Short-Form Test of Mental Maturity, Junior High Level

This test yields three mental age scores—language, non-language, and total. The scores are also interpretable in the form of deviation I.Q. scores.

Coefficients of reliability computed by the split-halves method and corrected by the Spearman-Brown formula are 0.93 for language, 0.89 for non-language, and 0.95 for total. Standard errors of measurement for mental ages are 7.7, 9.1, and 6.3 months, respectively (California Manual, 1963).

The validity claims of the publishers are based primarily on the original design of the test which evolved from a comprehensive analysis of the Stanford-Binet, and the test's high correlation with the individual Stanford-Binet and other intelligence tests.

Kuder General Interest Survey (Form E)

The Kuder General Interest Survey (1964 Edition) was developed in response to a need for such an instrument for use with younger people, particularly at the junior high level. It consists of ten scales, surveying interests in a wide range of activities. Among these ten interest areas is a Scientific Interest Scale.

Normative data for the Survey were developed in the spring of 1963, when the Survey was administered on a nationwide basis to a stratified sample of 6,950 boys and 6,565 girls in grades 6 through 12 from public elementary and secondary schools in the United States.

Approximately six weeks after administration of the Survey to the standardization sample, a randomly selected stratified sub-sample, consisting of 287 boys and 433 girls in grades 6-8 and 471 boys and 691 girls in grades 9-12, took the Survey a second time. Means, standard deviations, and test-retest correlations were calculated. Correlations were mainly in the 0.70s and 0.80s.

The Kuder-Richardson formula 20 was employed to check the internal consistency of the scales. Intercorrelations of the scales, for girls in the standardization sample, ranged from -.30 to +.37; for boys, from -.37 to +.35. Most of the correlations were close to zero.(Kuder Manual, 1964).

Unit Pre- and Posttest

The unit pre- and posttest was developed in anticipation of measuring pre- and post-experimental behavior in terms of both factual, science subject-matter competency, and the comprehension of scientific concepts, principles, and generalizations. The total test consisted of 50 multiple-choice items designed to cover the content of the curriculum of the six lessons in the unit. By jury validation, the 50 multiple-choice item test was judged to consist of 20 factual-oriented items and 30 conceptual-oriented items. The items were examined by the jury members for the specific fact or concept tested for in that item.

The test items, themselves, were revised after having been administered to the sixth-grade students participating in the original pilot tests, when the reading difficulty was questionable. Suggestions from the jury reviewers were incorporated in revising specific test items. The two participating seventh-grade teachers at Clarke County Junior High School also reviewed the test items.

The Test Scorer and Statistical Analysis 2 computer program was used to gain information on the testing instruments.[1]

For optimum discrimination a difficulty index of 0.50 is desirable. Table 2 and Table 3 in Appendix C give indices of item difficulty on the pretest and posttest used in this study. There were no extremely easy or extremly difficult items identified on either the pretest or the posttest. A comparison of the item difficulties between the two tests showed the difficulty levels of

the posttest to be more consistent among themselves than the difficulty levels of the pretest. Of the 50 items on the pretest, 24 items were of medium difficulty, 26 items were more difficult with an index of difficulty less than 0.40. Items are considered of medium difficulty with 40-50-60 percent passing.

On the posttest, 33 items were of medium difficulty, 10 items had an index of less than 0.40, and seven items were easier than those considered of moderate difficulty, with an index greater than 0.60.

An examination of Table 2 in Appendix C, showing the proportions choosing each of the four options for the fifty items on the pretest, demonstrates that each option was discriminating and served as a distractor. The proportion of the population choosing each item on the posttest is shown in Table 3.

The results of correlating each item with the total test are found in Table 4. Table 4, in Appendix C, lists the item difficulty, the standard deviation of the item, and the point biserial correlation of each item with the total test score on the pretest. The null hypothesis is rejected at either the 0.05 level or the 0.01 level or both for all except eight items on the pretest. An examination of the pretest standard deviations of items reveals that the majority of items have a deviation near or at 0.50.

Table 5, in Appendix C, refers to the same statistics for the posttest. Again item difficulty is shown along with the item standard deviation and the item-test correlation.

The null hypothesis is rejected at the 0.01 level of significance for all test items with the exception of item number 31 being significant at the 0.05 level, and items 11, 14, and 34 being nonsignificant. A total of 47 items out of 50 or 94 percent of the test items were significantly related to the total test score. Thus, 94 percent of the items apparently made a contribution to the total variance of the test.

Table 6 presents the mean, standard deviation, skewness, kurtosis, and standard error of each for the pre-factual test, pre-conceptual test, pre-total test, post-factual test, post-conceptual test, and post-total test. The raw score mean of the pre-total test was 19.54 with a $S_{\bar{X}}$ of 0.40, and a standard deviation of 5.92, with a S_{σ} of 0.24. Positive skewness was significant at the 0.05 level. Positive skewness is not unusual for a test in an area which has not been systematically pursued by students (i.e., by formal or informal classroom work). It is reasonable to suppose that a few students may have acquired some knowledge by independent study or informal inquiry, or even that an element of shrewdness in guessing (perhaps by narrowing four choices to two and improving the chances of a correct response without precise prior knowledge) may have permitted a few astute persons to obtain higher scores.

The raw score mean of the pre-factual test (total number of items = 20) was 7.86, with a $S_{\bar{X}}$ of 0.21, and a standard deviation of 3.07, with a S_{σ} of 0.13.

Pre-conceptual test raw score statistics for a total number

Table 6

Unadjusted Means, $S_{\bar{X}}$, Standard Deviation, S_{σ}, Skewness, S_{α_3}, Kurtosis, and S_{α_4}, for Pre- and Posttests

Statistic	Pre Factual	Pre Concept	Pre Total	Post Factual	Post Concept	Post Total
Mean	7.86	11.69	19.54	11.23	15.70	26.93
$S_{\bar{X}}$	0.21	0.26	0.40	0.24	0.34	0.53
S.D.	3.07	3.84	5.92	3.43	4.99	7.90
S_{σ}	0.13	0.17	0.24	0.14	0.20	0.30
Skewness(α_3)	0.11	0.27	0.42	-0.05	-0.02	0.00
S_{α_3}	0.16	0.16	0.16	0.16	0.16	0.16
Kurtosis(α_4)	-0.36	-0.18	-0.51	-0.69	-0.60	-0.70
S_{α_4}	0.33	0.33	0.33	0.33	0.33	0.33

of 30 items yielded a mean of 11.69 with a $S_{\bar{X}}$ of 0.26, and a standard deviation of 3.84, with a S_{σ} of 0.17.

Results for the total posttest revealed a raw score mean of 26.93, with a $S_{\bar{X}}$ of 0.53, and a standard deviation of 7.90, with a S_{σ} of 0.30. Kurtosis was significantly negative at the 0.05 level, indicating a relatively platykurtic curve.

Examination of post-factual test statistics disclosed a raw score mean of 11.23, with a $S_{\bar{X}}$ of 0.24, and a standard deviation of 3.54, with a S_{σ} of 0.14. Kurtosis was again significantly negative at the 0.05 level, describing a platykurtic curve.

Inspection of the post-conceptual test showed a mean of 15.70, with a $S_{\bar{X}}$ of 0.34, and a standard deviation of 4.99, with a S_{σ} of 0.20.

Test reliability was computed by the Kuder-Richardson formula 20. The reliability coefficient for the total pretest was 0.70. Treatment of data from the pre-factual-oriented subtest yielded a reliability coefficient of 0.58. The pre-conceptual-oriented subtest had a reliability coefficient of 0.57.

The reliability coefficient obtained for the total posttest was 0.84. Post-factual-oriented test reliability was 0.68; the post-conceptual-oriented subtest had a Kuder-Richardson coefficient of 0.74. A copy of the total test may be found in Appendix B.

Treatment of Data from Evaluation Questionnaire

In order to determine the students' reactions to the programming method, chi-square values were calculated from the responses to

the Evaluation Questionnaire.

The first ten questions provided three to five cells for the student's optional choice. The last two items on the questionnaire asked for a discussion of least-liked and most-liked features of the programmed laboratory materials. Representative comments from answers to items 11 and 12 are reported in Appendix D.

The questionnaire is included in Appendix B, and referred to by question number on Table 7, which summarizes the results of the analysis of the first ten questions of the questionnaire. For purposes of analysis the first two and the last two response categories are combined. The combined first two categories are referred to as the favorable category in all questions except number three, number six, and number eight in which the combined last two categories are referred to as the favorable category. The combined last two categories are referred to as the unfavorable category in all questions except numbers three, six, and eight in which the combined first two categories are referred to as the unfavorable category.

The hypothesis of independence of the response categories and classes was tested by computing chi-square for each of the ten questions on the questionnaire. If the hypothesis of independence is true, then the proportions of response in each of the three categories will be the same regardless of the class involved.

An examination of Table 7 which compares the favorable, indifferent, and unfavorable response categories, reveals that only question

Table 7

A Comparison of the Favorable, Indifferent, and Unfavorable Responses to the Evaluative Questionnaire

Question	Number of Responses	Type Response	df	χ^2	P
1	79 12 14	F I U	2	83.40	.01
2	88 9 8	F I U	2	110.40	.01
3	63 31 11	F I U	2	39.32	.01
4	42 23 40	F I U	2	12.22	.01
5	99 5 1	F I U	2	175.74	.01
6	98 0 7	F I U	2	170.80	.01
7	99 5 1	F I U	2	175.74	.01
8	96 0 9	F I U	2	161.60	.01
9	82 17 6	F I U	2	96.39	.01
10	86 11 8	F I U	2	111.59	.01

$\chi^2_{.95} = 5.99$

$\chi^2_{.99} = 9.20$

four has an equivalence of response. The preponderant favorable responses, to nine out of the ten objective questions on the evaluative questionnaire, were highly significant at the 0.01 level of significance.

Treatment of Data from Programmed Materials

Each of the six programmed, laboratory-experience lessons was checked to identify specific frames which elicited an incorrect response from the experimental subjects. A mean number of correct responses was computed for each of the six lessons, as well as the standard deviation. Lesson 1, "A Gradient: The Effect of pH on Yeast Activity", had a total of 77 frames with a mean number correctly answered of 71.38, and a standard deviation of 8.86.

For a total of 67 frames in Lesson 2, "A Gradient for the Separation of Chemical Substances: Paper Chromatography", a mean of 63.04 was obtained with a standard deviation of 7.07.

A mean of 98.62 resulted from the analysis of the frames answered correctly in Lesson 3, "Normal Curves and Warping Factors". The total possible number was 104 frames. The standard deviation was 10.75.

Lesson 4, "The Use of Normal Curves in Distinguishing Species", had a total of 89 frames with a mean number correct of 84.61, and a standard deviation of 9.44.

"A Study in Measurement", Lesson 5, was 182 frames in length. Comparatively, Lesson 5 was approximately twice the length of the other five lessons. Inasmuch as the use of the microscope was

necessary in this exercise, abundant illustrations and instructive frames were included in Lesson 5, along with the laboratory experiment itself. The mean number of correct frame responses was 175.53, with a standard deviation of 17.86.

For a total of 73 frames in Lesson 6, "Measurement as an Expression of Relationship: A Simple Balance", the mean correct was 70.22, with a standard deviation of 7.25.

Table 8, a correlation matrix for the six programmed, laboratory lessons, can be found in Appendix C, page 209.

Statistical Analysis

Analyses of variance and covariance were used to analyze the data. Because of disproportionate numbers in the groups being considered, a least-squares method of fitting constants was employed (Winer, 1961). Scores on reading vocabulary, reading comprehension, language intelligence, non-language intelligence, science average, Kuder General Interest Survey (Form E), the Unit Pretest, teacher, and sex were evaluated as to their effect on posttest scores with regard to factual and conceptual competencies in science. The categorized ability levels pointed out earlier were also covariates.

This is a treatment-by-levels statistical model in which the levels of the variables sex, ability, and achievement are not randomly selected. Use of the analysis of covariance technique allowed control over predicted differences between the experimental and control groups on the dependent variables. By adjusting for pretest differences,

this technique had the effect of controlling the students statistically.

CHAPTER IV

RESULTS

The least-squares analyses indicate the relationships between achievement as measured by the factual-oriented posttest, the conceptual-oriented posttest, and the total posttest scores, and the subject variables considered. They also indicate the relationship of scientific interest and the subject variables considered in the study. The 0.05 probability level was the criterion for rejecting the null hypothesis. By use of F tables, it was determined that for 200 degrees of freedom, an "F" ratio of 3.89 and 6.76 are significant at the 0.05 and 0.01 levels of significance, respectively.

<u>Achievement as Measured by the Posttest Factual Scores</u> (Table 9)

1. Evidence obtained from the analysis of the posttest factual scores of the experimental group and the control group indicates that the control group achieved at a significantly higher level than the experimental group ($F = 9.33$; $p < 0.01$).

2. Although the teacher variable did not prove to affect, significantly, the achievement of students, the interaction effects of treatment by teacher proved to be significant in favor of teacher one with the control group and teacher two with the experimental group ($F = 4.68$; $p < 0.05$).

3. Scores earned on the pre-factual test proved to be related positively to achievement on the post-factual test ($F = 5.37$; $p < 0.05$).

4. The relationship of science grades assigned by the seventh-grade science teachers for the first two quarters of the academic year, 1965-1966, proved to be significant ($F = 12.86$; $p < 0.01$).

5. Reading comprehension scores were positively related to achievement in the experimental program ($F = 7.28$; $p < 0.01$).

Table 9

Multiple Analysis of Variance and Covariance

for Posttest Factual Scores

Sources of Variation	df	Sum of Squares	Mean Square	F-value
Main Effects				
Sex	1	0.26	0.26	0.04
Teacher	1	0.50	0.50	0.08
Treatment	1	59.33	59.33	9.33**
Level	3	5.05	1.68	0.27
Interaction Effect				
Sex x Level	3	29.96	9.99	1.57
Sex x Treatment	1	0.11	0.11	0.02
Level x Treatment	3	5.30	1.76	0.28
Teacher x Treatment	1	29.74	29.74	4.68*
Covariates				
Pre-Factual Test	1	34.14	34.14	5.37*
Pre-Concept Test	1	13.90	13.90	2.19
Science Average	1	81.78	81.78	12.86**
Age	1	2.25	2.25	0.35
Reading vocabulary	1	1.25	1.25	0.20
Reading comprehension	1	46.29	46.29	7.28**
Language intelligence	1	2.68	2.68	0.42
Non-lang intelligence	1	11.12	11.12	1.75
Error	198	1259.64	6.36	
Total	220	2762.69	12.55	

*Significant at 0.05 level
**Significant at 0.01 level

6. No other subject variables made significant contributions to achievement in the experimental program for the posttest factual scores. These other variables were: sex, age, ability level, reading vocabulary scores as measured by the California Achievement Tests, Junior High Level, language and non-language intelligence scores as measured by the California Short-Form Test of Mental Maturity, Junior High Level, and the pretest conceptual scores. The teacher variable was not significant. Interactions of sex by level, sex by treatment, and level by treatment were nonsignificant.

Achievement as Measured by the Posttest Conceptual Scores (Table 10)

1. Analysis of the posttest conceptual scores of the experimental group and the control group reveals a positive significant achievement favoring the control group ($F = 8.92$; $p < 0.01$).

2. Interaction effects of treatment by teacher proved to be significant in favor of teacher one with the control group, and teacher two with the experimental group; although the teacher variable did not prove to effect, significantly, the achievement of students ($F = 7.49$; $p < 0.01$).

3. Scores earned on the pre-factual test proved to be related positively to achievement on the post-conceptual test ($F = 4.34$; $p < 0.05$).

4. A relationship was evidenced between the pre-conceptual test scores and achievement on the post-conceptual test scores ($F = 4.06$; $p < 0.05$).

5. Evidenced from the analysis of science grades assigned to the experimental and control populations by the seventh-grade science teachers for the first two quarters of the academic year, 1965-1966, these scores were related significantly ($F = 8.92$; $p < 0.01$).

6. Reading comprehension scores were highly significant as related to achievement in the experimental program ($F = 20.15$; $p < 0.01$).

7. No other subject variables made significant contributions to achievement in the experimental program for the posttest conceptual scores. These other variables were: sex, age, ability level, reading vocabulary scores, language and

Table 10

Multiple Analysis of Variance and Covariance

for Posttest Conceptual Scores

Sources of Variation	df	Sum of Squares	Mean Square	F-value
Main Effects				
Sex	1	15.87	15.87	1.52
Teacher	1	24.70	24.70	2.36
Treatment	1	93.39	93.39	8.92**
Level	3	63.33	21.11	2.02
Interaction Effect				
Sex x Level	3	94.29	31.43	3.00
Sex x Treatment	1	5.15	5.15	0.49
Level x Treatment	3	28.84	9.61	0.92
Teacher x Treatment	1	78.44	78.44	7.49**
Covariates				
Pre-Factual Test	1	55.94	55.94	5.34*
Pre-Conceptual Test	1	42.51	42.51	4.06*
Science Average	1	93.45	93.45	8.92*
Age	1	23.92	23.92	2.28
Reading vocabulary	1	0.09	0.09	0.01
Reading comprehension	1	211.06	211.06	20.15**
Language intelligence	1	4.62	4.62	0.44
Non-lang intelligence	1	3.92	3.92	0.37
Error	198	2073.68	10.47	
Total	220	5470.29	24.86	

*Significant at 0.05 level
**Significant at 0.01 level

non-language intelligence scores. The teacher variable was not significant. Interaction of sex by level, sex by treatment, and level were nonsignificant.

Achievement as Measured by the Total Posttest Scores (Table 11)

1. Evidence obtained from the analysis of the total posttest scores of the experimental group and the control group indicates that the control group achieved at a significantly higher level than the experimental group ($F = 14.20$; $p < 0.01$).

2. The interaction effects of teacher one with the control group and teacher two with the experimental group proved to be significant ($F = 8.75$; $p < 0.01$).

3. Science grades assigned by the teachers for the first two quarters of the academic year of 1965-1966, proved to be significant ($F = 15.15$; $p < 0.01$).

4. Reading comprehension scores were positively related to achievement on the total posttest ($F = 20.26$; $p < 0.01$).

5. Scores earned on the total pretest proved to be related positively to achievement on the total posttest ($F = 13.22$; $p < 0.01$).

6. No other subject variables made significant contributions to achievement in the experimental program for the total posttest. These other variables were sex, age, ability level, reading vocabulary scores, language and non-language intelligence scores. The teacher variable was not significant. Interaction of sex by level, sex by treatment, and level by treatment were nonsignificant.

The adjusted means for factual, conceptual, and total posttests for the several subgroups (sources of variation), are presented in Table 12, page 57.

Results of Adjusted Means for Factual, Conceptual, and Total Posttests (Table 12)

1. It is noted that the difference between treatments by teacher one were 2.20, 3.09, and 5.31 for the factual, conceptual, and total tests, respectively; whereas the difference

Table 11

Multiple Analysis of Variance and Covariance

For Posttest Total Scores

Sources of Variation	df	Sum of Squares	Mean Square	F-value
Main Effects				
Sex	1	21.72	21.72	0.96
Teacher	1	13.99	13.99	0.62
Treatment	1	320.66	320.66	14.20**
Level	3	88.26	29.42	1.30
Interaction Effect				
Sex x Level	3	221.99	74.00	3.28
Sex x Treatment	1	4.42	4.42	0.20
Level x Treatment	3	22.85	7.62	0.34
Teacher x Treatment	1	197.56	197.56	8.75**
Covariates				
Science Average	1	342.20	342.20	15.15**
Age	1	10.10	10.10	0.45
Reading vocabulary	1	1.17	1.17	0.05
Reading comprehension	1	457.64	457.64	20.26**
Language intelligence	1	14.62	14.62	0.65
Non-lang intelligence	1	28.71	28.71	1.27
Pretest Total	1	298.59	298.59	13.22**
Error	199	4494.43	22.59	
Total	220	13744.84	62.48	

*Significant at 0.05 level
**Significant at 0.01 level

Table 12

Adjusted Means for Factual, Conceptual, and Total Posttests

Sources of Variation	Tests: Factual	Conceptual	Total
Treatment			
Experimental (T_1)	10.53	15.00	25.35
Control (T_2)	11.83	16.63	28.36
Sex			
Male (S_1)	11.22	16.12	27.21
Female (S_2)	11.14	15.51	26.59
Teacher			
Teacher One (t_1)	11.12	16.22	27.16
Teacher Two (t_2)	11.24	15.41	26.55
I.Q. Level			
120 up (I_1)	11.54	16.16	27.56
105 - 119 (I_2)	11.32	15.77	26.95
90 - 104 (L_3)	10.87	14.74	25.51
75 - 89 (L_4)	10.99	15.05	26.31
Interaction - S x T			
Sex_1, $Treatment_1$	10.59	15.14	25.56
Sex_1, $Treatment_2$	11.84	17.11	28.87
Sex_2, $Treatment_1$	10.46	14.86	28.16
Sex_2, $Treatment_2$	11.81	16.15	27.84
Interaction - S x L			
Sex_1, $Level_1$	12.21	17.50	29.59
Sex_1, $Level_2$	11.21	15.46	26.59
Sex_1, $Level_3$	10.79	14.85	25.59
Sex_1, $Level_4$	10.66	15.57	27.34

Table 12

(Continued)

Sources of Variation	Tests		
	Factual	Conceptual	Total
Interaction - S x L (continued)			
Sex_2, $Level_1$	11.31	14.82	25.54
Sex_2, $Level_2$	11.42	16.09	27.32
Sex_2, $Level_3$	10.94	14.63	25.42
Sex_2, $Level_4$	11.31	14.53	25.28
Interaction - T x L			
$Treatment_1$, $Level_1$	11.17	15.30	28.12
$Treatment_1$, $Level_2$	10.69	14.38	24.97
$Treatment_1$, $Level_3$	10.14	13.86	23.82
$Treatment_1$, $Level_4$	10.49	13.54	24.40
$Treatment_2$, $Level_1$	11.91	17.03	28.80
$Treatment_2$, $Level_2$	11.94	17.16	28.94
$Treatment_2$, $Level_3$	11.59	15.63	27.19
$Treatment_2$, $Level_4$	12.24	16.56	28.22
Interaction - T x t			
$Treatment_1$, $Teacher_1$	10.02	14.68	24.50
$Treatment_1$, $Teacher_2$	11.04	15.32	26.21
$Treatment_2$, $Teacher_1$	12.22	17.77	29.81
$Treatment_2$, $Teacher_2$	11.44	15.49	26.90

between the treatments for teacher two were much smaller (.40, .17, and .69, respectively), thus accounting for the significant interaction.

2. Most noteworthy was that the adjusted means for the several I.Q. level groups were not only nonsignificant, but the difference between the highest and lowest groups were remarkably similar.

To analyze the differences in achievement gain for the control group and experimental group on all three tests, factual, conceptual, and total, a t test was performed. This test was performed on the raw scores corrected for chance by the formula rights minus one-third wrong, but did not take into account adjustments for covariates. The one-tailed test was used because it seemed most unlikely that the groups would lose proficiency as a result of systematic study. The one-tailed test is a more powerful test in this situation. A t ratio with 120 degrees of freedom, for a one-tailed test, has a value of 2.36 at the 0.01 level of significance.

Results of Testing Means of the Population of Differences (Table 13)

1. Evidence obtained from the analysis of means of differences for the factual test of the experimental and control groups, indicates that both groups had highly significant gains in achievement [$t = 11.03$ (Control); $t = 10.03$ (Experimental); $p < 0.01$].

2. Analysis of means of differences for the conceptual test of the experimental group and control group, reveals that both groups gained in achievement significantly [$t = 11.23$ (Control); $t = 7.76$ (Experimental); $p < 0.01$].

3. Data for the means of differences for the total test of the experimental and control groups demonstrated that both groups had highly significant achievement gains [$t = 13.06$ (Control); $t = 10.39$ (Experimental); $p < 0.01$].

The fourth hypothesis listed in Chapter I stated there would

Table 13

Unadjusted Corrected Means, Variances, Differences, Standard Errors of Differences, Correlations, and t Ratios for Control and Experimental Groups

	Control Group (N = 115)			Experimental Group (N = 106)		
	Factual	Conceptual	Total	Factual	Conceptual	Total
Pretest						
$\bar{X}$	3.27	4.36	7.12	5.35	8.06	13.00
s^2	11.02	17.47	47.47	13.69	19.71	51.27
Posttest						
$\bar{X}$	7.88	10.20	17.90	8.86	12.02	20.70
s^2	20.88	43.69	110.88	21.81	38.07	101.61
D(Post-Pre)	4.61	5.84	10.45	3.51	3.96	7.48
$s_{\bar{D}}$	.42	.52	.80	.35	.51	.72
$r_{Pre-Post}$	.39	.55	.59	.64	.54	.69
t	11.03	11.23	13.06	10.03	7.76	10.39

be no significant scientific interest change between the experimental and control groups. This hypothesis was tested by the least-squares multiple analysis of variance. Results of the treatment of the data are listed below.

<u>Multiple Analysis of Kuder General Interest Survey (Form E)</u> (Table 14)

1. Differences attributable to sex were significant at the 0.01 level of significance ($F = 13.47$; $p < 0.01$).

2. Differences attributable to teacher were significant at the 0.01 level of significance ($F = 33.55$; $p < 0.01$).

3. The pretest scores from the *Kuder General Interest Survey* were significant predictors for performance on the post-administration of the *Kuder General Interest Survey* ($F = 41.45$; $p < 0.01$).

Table 14

Multiple Analysis of Variance and Covariance for Scientific Scale of *Kuder General Interest Survey* (Form E)

Sources of Variation	df	Sum of Squares	Mean Square	F-value
Main Effects				
Sex	1	1041.96	1041.96	13.47**
Teacher	1	2595.13	2595.13	33.55**
Treatment	1	12.32	12.32	0.16
Level	3	124.09	41.36	0.54
Interaction Effect				
Sex x Level	3	308.47	102.82	1.33
Sex x Treatment	1	57.50	57.50	0.74
Level x Treatment	3	43.58	14.53	0.19
Teacher x Treatment	1	13.24	13.24	0.17
Covariates				
Science Average	1	76.10	76.10	0.98
Age	1	0.61	0.61	0.01
Reading vocabulary	1	51.72	51.72	0.67
Reading comprehension	1	9.11	9.11	0.12
Language intelligence	1	88.14	88.14	1.14
Non-lang intelligence	1	4.10	4.10	0.15
Pre-*Kuder* Test	1	3206.38	3206.38	41.45**
Error	199	15392.38	77.35	
Total	220	24010.02	109.13	

*Significant at 0.05 level
**Significant at 0.01 level

CHAPTER V

DISCUSSION AND CONCLUSIONS

The first three hypotheses are closely related, and the findings concerning them are consistent. Discussion related to them will be on a collective basis.

Those students pursuing the program of instruction employing the non-programmed, problem-solving approach achieved at a significantly higher level than was achieved by members of the experimental group. However, evidence clearly suggests that those students having the ability to pursue, adequately, a problem-solving, general science unit did so in both the experimental and the control group. The results of testing means of the population of differences revealed highly significant t ratios beyond the 0.01 level for both the experimental and control groups for all three tests, factual, conceptual, and total. This means that not only were definite gains made in science, factual knowledge; but, also, definite gains in ability to use concepts, generalizations, and principles as measured by the pre- and post-conceptual test, were evident for both groups. Thus, the open-ended, problem-solving aspect of the experimental program appeared to be successful for both experimental and control groups.

As revealed in Table 13, page 60, the relative gain for the control group was greater. The raw score mean for the experimental group was higher, but after adjustment, which takes into account all covariates, the adjusted means were reversed for the groups. On the factual pretest, the control group mean was 3.27, that of the

experimental 5.35. Factual posttest means for the control and experimental were 7.88 and 8.86, respectively. The difference score for the control group was 4.61, for the experimental 3.51. Thus, the relative gain was higher for the control group.

This is demonstrated also from treatment of the data for the conceptual pre- and posttest. The raw score means for the control were 4.36 and 10.20, for the experimental, 8.06 and 12.02. Differences were 5.84 and 3.96, respectively, for the control and experimental groups.

Differences for the total pre- and posttest were 10.45 for the control, and 7.48 for the experimental. Raw score means were 7.12 and 17.90 for the control, and 13.00 and 20.70 for the experimental.

Thus, the control group started at a relative disadvantage as compared with the experimental group, but made a significantly greater gain. In spite of the relatively greater gain of the control group for all criteria, the experimental raw means were still superior at the end of the experiment.

To look at some contributions of the programmed approach, the teachers of the experimental groups and the investigator, by observation, noted a change in the general work patterns of the members of the experimental group. The program seemed to be highly motivating to the students. Generally, they reported promptly to the classroom, started to work immediately, and continued to work during the entire class period. The principal and one of the cooperating teachers both commented on the wonder of seeing some apathetic students participating in any project for the first time. One of the teachers commented that

several of the lower ability students, by proceeding at their own pace, were finally able to succeed at something, and to gain satisfaction from their accomplishment. Another student, contributed one teacher, talked more during the first week of experimentation than he had all year; he wanted to discuss his research findings about which he was apparently intrigued. Some students mentioned they were really understanding the metric system for the first time, inasmuch as they were actually working with metric units of measurement in the collection of their data.

The reaction to the programmed sequence ranged from enthusiasm to mere acceptance. Most of the students reactions were highly enthusiastic as demonstrated by the results of the evaluative questionnaire discussed in Chapter III.

There appeared to be no unusually difficult administrative problems surrounding the individual performances of laboratory experiments by these seventh-grade students. Breakage or destruction of supplies and equipment was surprisingly minor. Generally students developed laboratory skills rapidly.

The experimental group had the advantage in that those students who were absent from class could, upon their return, enter the program at the point they had left before the absence. There was no loss of instructional time due to the absence. The student could take his programmed material home during his absence also. As a result, all members of the experimental group were exposed to precisely the same content. This was not true in the control group where, because of

procedures used in conventional methods of presentation, the student missed the content of the instructional activities in the classroom when he was absent.

Teacher

The statistical treatment revealed that there was no significant teacher difference which contributed to the achievement of the student in the program. Inasmuch as the content of instructional materials was identical, this result seems plausible.

Level

There is no statistical evidence to indicate a significant relationship between the level of ability of the student and his performance at the conclusion of the instructional program. A possible explanation is that with many other factors controlled, there was little remaining for intelligence to contribute when considered separately.

Sex

The statistical treatment demonstrated no significant relationship between sex of the student and achievement in the program. Although there was no significant difference, the mean of the posttest scores for boys was higher than for girls. Evidence cited by other investigators was inconsistent; some investigators reported sex differences in favor of boys, and still other investigators reported no significant relationship between sex and achievement where programmed instruction was used.

Interaction of Main Effects

Sex by Treatment

No supportive evidence contributed to a significant difference between sexes and the type of treatment they were under.

Sex by Level

Results of the analysis of the interaction of sex by level of ability were nonsignificant.

Treatment by Level

Treatment of the data yielded a nonsignificant F-value for the interaction effect of treatment by ability level. This surprising lack of significance of differences was unexpected. Not only were there no significant differences among the ability levels by treatment, but the range of achievement from the high ability group to the low ability group was not consistent. Referring to Table 12, page 57, it is noted that the low ability level (L_4) responded well to the contol treatment (T_2), consistently excelling level three on the factual, conceptual, and total tests. On the factual test level four's adjusted mean exceeded all other levels. This apparently unusual finding may open a possible door for the lower ability groups by building general science curriculum around activity-centered, problem-solving, laboratory demonstrations.

Treatment by Teacher

Looking at both factors in this interaction, there is a significant treatment difference with a nonsignificant teacher difference, but the treatments were significant for the respective teachers.

Comparison of adjusted means in Table 12, page 57, demonstrates this diffcrence. Treatment one was significant for teacher two; treatment two was significant for teacher one. The effectiveness of programming may depend to some extent upon the teacher. A teacher whose approach is more personalized, and whose effectiveness depends upon the unique constellation of personal traits, may find programming less effective than the conventional procedures. Programming may be more effective in combination with a particular type of teacher. It will not replace the reassuring direction of a competent teacher. Where relationships may be somewhat impersonal, and motivation of learners is reasonably assurred, programming may be relatively more effective. Further research on this aspect may be enlightening.

Covariates

Science Average

The science average assigned by the cooperating teachers during the first two quarters of the academic year, 1965-1966, contributed significantly as a predictor of achievement in the unit of instruction. This F-ratio was highly significant beyond the 0.01 level. Findings contrary would not be expected inasmuch as the best indicator of a student's performance in a subject area is his past performance in that respective area.

Reading Scores

Reading comprehension scores contributed more as a prediction factor than any other considered variable. This finding is to be expected, and further emphasizes the essential need for adequate

foundations in reading skills, particularly as it is related to the ability to comprehend scientific material.

Intelligence

Intelligence was not found to be related to general science achievement significantly. This finding is not consistent with the findings of Shay (1961), Keislar (1959), McNeil and Keislar (1961), and Andrews (1963), all of whom investigated the relationship of intelligence to success in programmed instruction. Again, a possible explanation is that with the pretest and many other factors controlled, there was little remaining for intelligence to contribute when considered separately.

Pretest Score

The pretest score was a significant predictor of achievement in the experimental program since the items constituting the test were representative of the content of the experimental instruction.

Kuder General Interest Survey (Form E)

There was no significant change in science interest patterns among the experimental and control populations after the experimentation. However, the teacher difference was highly significant.

Conclusions

The following conclusions, in terms of the stated hypotheses are warranted on the basis of the findings presented in this study. Generalizations drawn from them should be limited to similar groups pursuing programmed instruction under similar conditions.

1. Students can achieve at significantly higher levels in factual, science subject-matter through the use of a non-programmed, open-ended approach to seventh-grade, general science instruction.

2. Students can achieve at significantly higher levels in conceptual, science subject-matter through the use of a non-programmed, open-ended approach to seventh-grade, general science instruction.

3. Students can achieve at significantly higher levels in factual and conceptual, science subject-matter through the use of a non-programmed, open-ended approach to seventh-grade, general science instruction.

4. No significant scientific interest change results from an interdisciplinary, general science unit of the nature used in this research project.

The following conclusions, while not within the scope of the stated objectives, can be made from the supportive data of the study.

1. Previous performance in general science is a reliable predictor of success in general science taught by non-programmed or programmed materials.

2. There is a positive relationship between reading comprehension scores as measured by the <u>California Achievement Test, Junior High Level</u>, and achievement in an open-ended problem-solving approach to seventh-grade general science.

3. Boys and girls achieve at approximately the same level in general science materials.

4. A pretest score is a reliable predictor of achievement in seventh-grade general science instructional materials.

5. Programming may be more effective in combination with a particular type of teacher.

6. There is no relationship between intelligence as measured by the <u>California Short-Form Test of Mental Maturity, Junior High Level</u>, and achievement in the non-programmed or programmed sequence of general science.

CHAPTER VI

SUMMARY AND IMPLICATIONS

Purposes and Objectives of Problem

The purpose of this study was to ascertain the effectiveness of a non-programmed, problem-solving method of teaching seventh-grade general science, and that of a problem-solving approach through selected, open-ended, laboratory experiences. Particular reference was given to any significant change in factual, science, subject-matter competency, comprehension of scientific concepts, principles, and generalizations, and in scientific interest.

The specific objectives are listed below.

1. To compare the data for any significant gains in factual, subject-matter competency as measured by the factual-oriented posttest.
2. To compare the data for any significant gain in the comprehension of scientific concepts, principles, and generalizations as measured by the conceptual-oriented posttest.
3. To determine the difference between the mean achievement of students using programmed materials and the mean achievement of students using the non-programmed approach as measured by the total posttest.
4. To ascertain if there are differences between the effects of the two approaches concerning development of interest

in science as measured by the Kuder General Interest Survey (Form E).

Significance of Problem

In teaching science, a continuing area of concern to educators has been the problem of integrating laboratory experimentation with scientific theory. The need to individualize course content for students is also recognized. Programmed instruction may offer one solution to both these difficulties. If the science curriculum can be programmed so that individual rates of learning can be dealt with more effectively, and if laboratory materials can be developed which enable students to conduct experiments efficiently on an individual basis, laboratory experimentation will be integrated more satisfactorily into the typical science course.

Related Research

The research reviewed was limited to a summary of the development of programmed instruction, studies dealing with programmed instruction, reviews of programmed science materials, and research related to programmed laboratory experiences.

Among representative research dealing with programmed instruction, Coulson and Silberman (1960), Fry (1960), and Larkin and Keith (1964), reported the constructed-response or linear method to be superior for recall. Studies of the relationships among intelligence, sox, and achievement during programmed instruction were reported by Shay

(1961), Keislar (1959), McNeil and Keislar (1961), and Andrews (1963). All reported a positive relationship between intelligence and achievement, but findings were inconsistent in regard to sex differences. A positive relationship between intelligence and mathematics achievement was reported by Andrews (1963).

Data reported for studies which were related to programmed, science material showed significant achievement differences in favor of the experimental groups. Pollard (1964) found a significant difference in favor of the experimental group using a card deck unit in biology. Lawson (1960) using a one-week, scrambled-book, genetics unit reported significance beyond the 0.01 level in favor of the programmed approach. Reush and Cornell (1963) tested an edition of a program on molecular equilibrium, and reported an increase in grade average as a result of the programmed material.

Few research projects involving programmed, laboratory, science experiences were found. Among those cited, only two reported data analyses. Wash (1964) conducted an experiment in the use of programmed materials in teaching high school chemistry, reporting that students can achieve at significantly higher levels through the use of laboratory exercises with a programmed chemistry sequence. A year-long use of programmed science materials with laboratory experiences on the fourth-grade level, as reported by Hedges and MacDougall (1965), revealed no significant differences in achievement. However, the groups using programmed, laboratory experiences enjoyed their method of learning considerably better.

Experimental Design

To obtain data relevant to the objectives of this study, research design number 10 proposed by Campbell and Stanley (1963), was considered appropriate. The four main effect variables, the interaction effect variables, and the covariates of the research design are listed below.

Main effects:

1. Treatment
2. Teacher
3. Sex
4. Ability level

Interaction effects:

1. Sex by level
2. Sex by treatment
3. Treatment by level
4. Treatment by teacher

Covariates:

1. Age
2. Reading vocabulary
3. Reading comprehension
4. Language intelligence
5. Non-language intelligence
6. Science average
7. Unit pretest

Sampling Procedure

The subjects in this study were samples of the population of students enrolled in the seventh grade of the Clarke County High School during the academic year, 1965-1966. The total seventh-grade population was assigned to four academic teams of teachers. Each team consisted of four teachers who instructed students in respective

areas of English, mathematics, history, or science. The team-student population was divided into four sections, with each section consisting of approximately 30 students. The investigator used subjects from two academic teams, one population with N = 118, and the other with N = 103. A total of eight sections were involved with N = 221.

Two science teachers from two academic teams participated in this study. Both cooperating teachers instructed two experimental and two control groups.

The Program

A programmed sequence was developed for use in this study from June, 1965 to December, 1965, by the investigator. Pilot studies were conducted for the purpose of revising the program, and laboratory exercises were tested. The final version of the program contained six lessons of an interdisciplinary nature totalling 590 modified linear frames.

Description of the Treatments

In the experimental sections the teachers were instructed not to use any materials for total classroom instruction other than the programmed, laboratory materials. Using the non-programmed materials provided by the investigator, the teachers instructed the control sections in their usual manner. The principal, special instruction for the teaching of the control groups was that no programmed materials were to be used in their classes. Also there were to be only teacher-

demonstrations, and no individual experiments. The approach was one of problem-solving in both experimental and control groups.

Initially, students in the experimental group and control group were administered a pretest. At the conclusion of the instructional period, the posttest was administered to both the control and experimental groups. The Kuder General Interest Survey (Form E) was also administered to both the control and experimental groups. The evaluation questionnaire, designed to elicit a student, subjective response toward the method of programming laboratory experiences, was administered to the experimentals at the end of the instructional period.

Sources and Types of Data

The data were obtained from six main sources: (a) records in the Clarke County Guidance Department, (b) cumulative record cards from the principal's office, (c) the administration of the Kuder General Interest Survey (Form E) (d) the administration of the unit pre- and posttest, (e) the administration of the evaluative questionnaire, and (f) the record of the number of frames missed in each respective programmed lesson.

Testing Instrument for Unit Pre- and Posttest

The unit pre- and posttest was developed in anticipation of measuring pre- and post-experimental behavior in terms of both factual, science subject-matter competency, and the comprehension of scientific concepts, principles, and generalizations. The total test consisted

of 50 multiple-choice items designed to cover the content of the curriculum of the six lessons in the unit. By jury validation, the 50 multiple-choice item test was judged to consist of 20 factual-oriented items and 30 conceptual-oriented items. The items were examined by the jury members for the specific fact or concept tested for in that item.

The test items, themselves, were revised after having been administered to the sixth-grade students participating in the original pilot tests, when the reading difficulty was questionable. Suggestions from the jury reviewers were incorporated in revising specific test items. The two participating seventh-grade teachers at Clarke County Junior High School also reviewed the test items.

Test reliability was computed by the Kuder-Richardson formula 20. The reliability coefficient for the total pretest was 0.70. Treatment of data from the pre-factual-oriented test yielded a reliability coefficient of 0.58. The pre-conceptual-oriented test had a reliability coefficient of 0.57.

The reliability coefficient obtained for the total posttest was 0.84. Post-factual-oriented test reliability was 0.68; the post-conceptual-oriented test had a Kuder-Richardson coefficient of 0.74.

Treatment of Data from Evaluation Questionnaire

In order to determine the students' reactions to the programming method, chi-square values were calculated from the responses to the Evaluation Questionnaire, and the hypothesis of independence of the response categories and classes was tested. Examination of the

data revealed that nine out of the ten objective questions on the evaluative questionnaire had preponderant favorable responses, highly significant at the 0.01 level. Representative comments from responses to items 11 and 12 are reported in Appendix D.

Treatment of Data from Programmed Materials

Mean numbers of correct responses computed on each of the six programmed lessons were satisfactory. An average of 4.5 incorrect frames was reported out of an average length of 100 frames per lesson.

Statistical Procedure

Analyses of variance and covariance were used to analyze the data. Because of disproportionate numbers in the groups being considered, a least-squares method of fitting constants was employed. Scores on reading vocabulary, reading comprehension, language intelligence, non-language intelligence, science average, Kuder General Interest Survey (Form E), the Unit Pretest, teacher, and sex were evaluated as to their effect on posttest scores with regard to factual and conceptual competencies in science. The categorized ability levels were also covariates. The 0.05 probability level was used as the criterion for rejecting the null hypothesis.

Results and Discussion of the Study

Data obtained from the experimental and statistical procedures described previously revealed the following relationships pursuant to

the objectives of the study. The achievement of the members of the control group, as measured by the factual, conceptual, and total posttest scores, was significantly higher than the achievement of the experimental group. However, evidence clearly suggests that those students having the ability to pursue, adequately, a problem-solving, general science unit did so in both the experimental and the control group. The results of testing means of the population of differences revealed highly significant t ratios beyond the 0.01 level for both the experimental and control groups for all three tests, factual, conceptual, and total. This means that not only were definite gains made in science, factual knowledge; but, also definite gains in ability to use concepts, generalizations, and principles as measured by the pre- and post-conceptual test, were evident for both groups. Thus, the open-ended, problem-solving aspect of the experimental program appeared to be successful for both experimental and control groups.

Significant differences found among the sources of variation in the analysis of the Kuder General Interest Survey (Form E) data related to sex, teachers, and pre-Kuder scores. Differences attributable to sex, teacher, and pre-Kuder scores were significant at the 0.01 level of significance.

Positive contributions of the programmed approach were seen in the work habits of the students, their increasing ability to work independently, their enthusiasm in conducting laboratory experiments individually, and their development of laboratory skills called for within the programmed sequence. The experimental group had an advantage

in that those students who were absent from class, could, upon their return, enter the program at the point they had left. The student could also take his programmed materials home.

Scores on the pretest proved to be related positively to achievement on the posttest. The relationship of science grades assigned by the seventh-grade science teachers for the first two quarters of the academic year, 1965-1966, proved to be significant. Reading comprehension scores were positively related to achievement in the experimental program. No other subject variables made significant contributions to achievement in the experimental program for the posttest scores.

Interaction effects of sex by treatment, sex by level, and treatment by level were nonsignificant. The surprising lack of significance for the interaction of treatment by level was unexpected. Not only were there no significant differences among the ability levels by treatment, but the range of achievement from the high ability group to the low ability group was not consistent. The lowest ability level consistently excelled level three on the factual, conceptual, and total tests. On the factual test, level four's adjusted mean exceeded all other levels. This apparently unusual finding may open a possible door for the lower ability groups by building general science curriculum around activity-centered, problem-solving, laboratory demonstrations.

The interaction effect of treatment by teacher was significant. Treatment one was significant for teacher two; treatment two was significant for teacher one. The effectiveness of programming may

depend to some extent upon the teacher. A teacher whose approach is more personalized may find programming less efffective than the conventional procedures.

Conclusions

The following conclusions, in terms of the stated hypotheses are warranted on the basis of the findings presented in this study. Generalizations drawn from them should be limited to similar groups pursuing programmed instruction under similar conditions.

1. Students can achieve at significantly higher levels in factual, science subject-matter through the use of a non-programmed, open-ended approach to seventh-grade, general science instruction.

2. Students can achieve at significantly higher levels in conceptual, science subject-matter through the use of a non-programmed, open-ended approach to seventh-grade, general science instruction.

3. Students can achieve at significantly higher levels in factual and conceptual, science subject-matter through the use of a non-programmed, open-ended approach to seventh-grade, general science instruction.

4. No significant scientific interest change results from an interdisciplinary, general science unit of the nature used in this research project.

The following conclusions, while not within the scope of the stated objectives, can be made from the supportive data of the study.

1. Previous performance in general science is a reliable predictor of success in general science taught by non-programmed or programmed materials.

2. There is a positive relationship between reading comprehension scores as measured by the <u>California Achievement Test, Junior High Level</u>, and achievement in an open-ended problem-solving approach to seventh-grade general science.

3. Boys and girls achieve at approximately the same level in general science materials.

4. A pretest score is a reliable predictor of achievement in seventh-grade general science instructional materials.

5. Programming may be more effective in combination with a particular type of teacher.

6. There is no relationship between intelligence as measured by the _California Short-Form Test of Mental Maturity, Junior High Level_, and achievement in the non-programmed or programmed sequence of general science.

Implications for Further Research

As is true with most studies, the investigation reported here has yielded answers to the problem under study, and, concomitantly, has suggested other areas for research in the fields of general science and programmed instruction. Problems suggested for further study are:

1. Investigation into the personality traits of the student, such as maturity, emotional stability, ability, ego strength, curiosity, and sufficiency to determine the relationship of a student's success with programming to these traits.

2. Investigation into the personality traits of the teacher in more depth to determine the extent to which effectiveness of programming depends upon the instructor.

3. A more extensive experiment employing programmed materials containing laboratory experiences is needed to determine the long-term effects of such an instructional procedure.

4. The study of reading and reading problems and their implications for programmed instruction in terms of achievement and instructional time necessary for maximum learning.

5. Investigation into the instructional time requirements for programmed materials of this nature for maximum benefit to the students.

6. Development of a research plan to use the investigator's

programmed materials with other grade levels to determine the readiness of other grade levels for self-instruction.

7. Modification of the investigator's research plan to include adequate discussion sessions at the end of each programmed lesson to clarify faulty concepts.

8. Development of programmed laboratory experiences incorporating more concepts other than the three main ideas used by the investigator.

9. Development of activity-centered general science curriculum for lower ability groups.

BIBLIOGRAPHY

Alter, M. Retention as a function of length of retention interval, intelligence, and training time. Journal of Programed Instruction, 1963, 2, 7-17.

Andrews, Mary M. Programed instruction in elementary school: a study of variables associated with mathematics achievement. Unpublished doctoral dissertation. University of Georgia, 1963.

Arnstine, D. G. Programmed instruction and unit teaching, High School Journal, 1964, 47, 194-200.

California Manual. California achievement tests. Los Angeles: California Test Bureau, 1963, p. 8.

California Manual. California short-form test of mental maturity. Los Angeles: California Test Bureau, 1957, p.3.

Campbell, D. T., & Stanley, J. C. Experimental and quasiexperimental designs for research on teaching. In N. L. Gage (Ed.) Handbook of Research on Teaching. New York: Rand-McNally, 1963.

Cohen, I. & Fetterolf, R. Programmed instruction in qualitative analysis laboratory. Journal of Chemical Education, 1963, 40, 25-26.

Coulson, J. E. & Silberman, H. F. Effects of three variables on a teaching machine. Journal of Educational Psychology, 51, 1960, 135-143.

Crowder, N. Automatic tutoring by means of intrinic programming. In E. H. Galanter (Ed.), Automatic teaching: the state of the art. New York: John Wiley and Sons, 1959.

Englemann, M. D. Construction and evaluation of programmed materials in biology classroom use. American Biology Teacher, 1963, 25, 212-213.

Das, R. C. T. problem development method: an experimental try-out in the teac. g of science in secondary schools. Science Education, 1964, 48, 485-488.

Fry, E. B. Teaching machines: an investigation of constructed versus multiple-choice methods of response. In A. A. Lumsdaine & R. Glaser (Ed.), Teaching machines and programmed learning. Washington, D.C.: National Education Association, 1960.

Fry, L. B. Teaching machines: the coming automation. Phi Delta Kappan, 1959.

Geller, M. S. Pupils' attitudes toward programed learning. Science Teacher, 1963, 30, 41-42.

Gilbert, T. F. On the relevance of laboratory investigation of learning to self-instructional programming. In A. A. Lumsdaine & R. Glaser (Eds.), Teaching machines and programmed learning. Washington, D.C.: National Education Association, 1960, 517-539.

Goldberg, M. H. Comparison of programmed and conventional instruction methods. Journal of Applied Psychology, 1964, 48, 110-114.

Green, E. J. The learning process and programmed instruction. New York: Holt, Rinehart and Winston, Inc., 1963.

Hanson, L. T. Schools using programed materials. Audiovisual Instruction, 1963, 8, 101-103.

Hedges, W. D., & MacDougall, M. A. Teaching fourth grade science by means of programmed science materials with laboratory experiences. Science Education, 1964, 48, 64-76.

Hedges, W. D., & MacDougall, M. A. Teaching fourth grade science by means of programmed science materials with laboratory experiences, phase III. Science Education, 1965, 49, 348-358.

Hilgard, E. R. Theories of learning and instruction. The sixty-third yearbook of the national society for the study of education, Part I, 1964.

Hughes, J. L. Programed instruction for schools and industry. Chicago: Science Research Associates, Inc., 1962.

Humphreys, A. H. A critical analysis of the use of laboratories and consultants in junior high school science courses. Unpublished doctoral dissertation. University of Texas, 1962.

Kuder Manual. Kuder general interest survey (form E). Chicago: Science Research Associates, Inc., 1964.

Larkin, T. C. A comparison of linear and branching methods of programmed instruction in a secondary school. Educational Review, 1964, 40, 269-282.

Larkin, T. C., & Keith, G. M. The effects of linear and branching methods of programmed instruction on learning and retention of a topic in elementary science. Programed Learning, 1964, 1, 12-16.

Lawson, C. A., Burmester, M. A., & Nelson, C. H. Developing a scrambled book and measuring its effectiveness as an aid to learning

natural science. Science Education, 1960, 44, 347-358.

Leahy, D. J., & Siegel, B. N. The science teacher and programmed instruction. Science Teacher, 1962, 29, 40-41.

Lysaught, J. P., & Williams, C. M. A guide to programmed instruction. New York: John Wiley & Sons, Inc., 1963.

Mager, R. F. Preparing objectives for programmed instruction. San Francisco: Pearson Publishers, 1961.

Michigan Department of Public Instruction. Open-ended laboratory-centered science for grades 7-8-9. Lansing, Michigan: Department of Public Instruction, 1965.

Navarra, J. G. Developing generalizations in elementary science. Science Education, 1963, 47, 245-250.

Norton, J. E. The need for an activity-centered science program. Science Education, 1963, 47, 285-291.

Pollard, W. N. Use of a card deck unit in teaching biology. American Biology Teacher, 1964, 26, 203-206.

Powell, V. P. Programmed instruction in high school chemistry. Journal of Chemical Education, 1963, 40, 23-24.

Pressey, S. L. A simple apparatus which gives tests and scores—and teaches. School and Society, 1926, 23, 586.

Probst, L. Programmed learning in the schools. Science Teacher, 1962, 29, 34-35.

Reusch, R. N. & Cornell, P. H. An experimental program on chemical equilibrium. Journal of Chemical Education, 1963, 40, 27-28.

Schippers, J. V. An investigation of the problem method of instruction in sixth-grade science classes. Unpublished doctoral dissertation. State University of Iowa, 1962.

Shay, C. Relationship of intelligence to step-size on a teaching machine program. Journal of Educational Psychology, 1961, 52, 98-103.

Silberman, H. F. Self teaching devices and programmed materials. Review of Educational Research, 1962, 17, 179-193.

Skinner, B. F. The science of learning and the art of teaching. Harvard Educational Review, 1954, 24, 86-97.

Stolurow, L. M. Implications of current research and future trends. _Journal of Educational Research_, 1962, _55_, 519-527.

Travers, R. W. _Essentials of learning_. New York: The MacMillan Company, 1963.

Van Deventer, W. C. Teaching of science at the college and university level; programmed instruction. _Review of Educational Research_, 1964, _34_, 337-339.

Van Deventer, W. C. Michigan prepared project on junior high school science. _Science Teacher_, 1963, _31_, 29-30.

Wash, J. A., Jr. An experiment in the use of programed materials in teaching high school chemistry. Unpublished doctoral dissertation. University of Georgia, 1964.

Winer, B. J. _Statistical principles in experimental design_. New York: McGraw-Hill, 1952.

Wong, H. K. Programming a high school biology course. _American Biology Teacher_, 1964, _26_, 169-172.

Zabka, R. A field study contrasting programmed instruction and the traditional classroom presentation in grades seven and eight. Unpublished doctoral dissertation.

FOOTNOTE

[1]Wolf, R., & Klopfer, L. Test scorer and statistical analysis 2. Chicago: The University of Chicago, 1963. Unpublished mimeographed paper.

APPENDIX A

A GRADIENT: THE EFFECT OF pH ON YEAST ACTIVITY

Section__________ Name____________________________

1. Every living organism and every bit of non-living matter interacts with the things around it. Nothing exists alone. Therefore, no humans, animals, or non-living matter exists ______________________________.

alone

2. Humans and animals depend upon plants for their energy. Plants in turn depend upon the sun for their energy. Therefore, every living organism ____________________ upon something else for energy.

depends

3. Any surrounding circumstance, condition, or influence with which an organism or object changes or interacts is called its environment. Every organism or object interacts with its environment and because of this is ____________ upon its environment.

dependent

4. Nothing really stands still either. Everything in the universe is constantly changing and the kind of change depends upon the type of ________________________.

environment

5. Plants and animals must carry on activity internally, inside, to provide energy for life. This activity is called metabolism which means "change". Internally, plants and animals are constantly ______________________ also.

changing

6. This activity or metabolism takes place within the cell. Energy is released in proportion to the rate of metabolism. Cellular release of energy is called ________________.

metabolism

7. The rate of change or metabolic activity can be measured. The amount of oxygen inhaled or used is compared with the amount of carbon dioxide exhaled or given off. From what has been mentioned before, this rate will be ______________________ upon the environment.

dependent

8. In the yeast we can determine activity by the rate at which carbon dioxide is produced also. However, unlike humans, they may live without consuming oxygen. Air is not necessary because they may live without consuming ________.

oxygen

9. A part of our environment is made up of a multitude of living things that are too small to be seen with the naked eye. These are called microorganisms. Yeasts cannot be

microorganisms	seen with the naked eye so they are called ______ ______.
carbon dioxide	10. In our experiment we will construct a series of gradually changing environments, and demonstrate that the growth of yeasts varies with their environment. As was mentioned earlier, we will measure this activity by the rate at which yeasts produce the gas, ______ ______.
carbon dioxide	11. Carbohydrates, the class of foods to which sugars belong, are used by yeasts to provide energy, and carbon dioxide is given off, as one end product. We shall use sucrose, regular table sugar, which is a carbohydrate. An end product of the breakdown of sucrose is ______ ______.
one atom of carbon	12. Carbon dioxide is the gas, you will recall, which we exhale as waste and which plants use in photosynthesis. The symbols for carbon dioxide are: CO_2. If "O_2" stands for two atoms of oxygen, "C" stands for ______ ______ ______ ______.
carbon dioxide ethyl alcohol (either order)	13. Another process resulting in sugar breakdown is called fermentation. The end product of the fermentation of sugar is <u>ethyl alcohol</u>. We could say, then, that the fermentation of sucrose generally results in ______ ______ and ______ ______.
microorganisms sugar or sucrose carbon dioxide ethyl alcohol gas the breakdown of sugar or carbohydrates	14. Now to summarize what you have learned so far: Yeasts are ______ that carry on fermentation of the carbohydrate that we term ______. Energy is given off as well as ______ ______ and ______ ______ as end products. CO_2 is a ______. Fermentation of carbohydrates can be defined as ______.
acid	15. In our experiment we shall use environments which will <u>gradually change</u> from an acid to a base. Sourness is an <u>acid</u> quality. A <u>base</u> demonstrates a sharp, bitter, stinging taste. Vinegar has a sour taste so it would be considered a (an) ______.
acid	16. Would you judge a grapefruit to be an acid or base? ______
	17. Have you ever tasted a solution of baking soda when you

bitter or stinging

had an upset stomach? How did it taste? ________________

base

18. Baking soda would be considered a (an) ______________.

bitter or stinging

19. Alkaline is another word for base. An alkaline solution would taste ____.

8 to 14

20. A scale is used to determine the acidity or alkalinity of a solution. The scale used is called a pH scale, and ranges from 1 to 14. Seven is neutral. Acids range from 1 to 6; bases would range from _________ to ____________.

sour

21. A solution with high acidity would taste very ________.

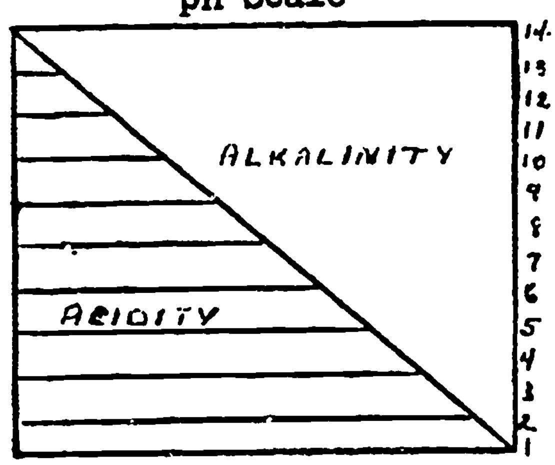
bitter, stinging

22. High alkalinity of a solution would cause it to taste quite _____________ and ___________________________.

alkaline

23. A pH of 7 is neutral, neither acid nor base. In the figure on the right, the plain area represents alkalinity, the lined, acidity. Using the vertical side, locate a pH of 14. Viewing it across, horizontally, would you say a pH of 14 would be alkaline or acidic? ______________

pH Scale



acidic

24. According to the figure what would a pH of 1 be, acidic or alkaline? ________________________________

acidic, acidic
alkaline, alkaline

25. Referring to the figure again, what would a pH of 3 be considered? ________________ of 4? ___________ of 12? ____________________ of 8? ______________________

1 to 6

26. From your consideration of the pH scale, the numbers from 1-14 which would denote an acidic condition would be from __________ to ______________________________.

8

27. An alkaline condition would range from _________ to 14.

28. Earlier we said a series of environments could be con-

structed to constitute a gradual change from extreme sourness to extreme bitterness. This is called going from acidity to ____________.

alkalinity

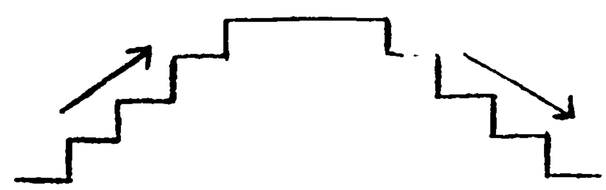
---

29. The word gradient comes from the Latin word gradiens meaning to step, to walk. As you walk up a set of steps there is a change in your elevation gradually, from the ground level. You would be ascending at a uniform slope. This could be an example of a ____________.

gradient

---

30. Should you then walk back down those steps, you would be decending at a uniform speed and your change in elevation from the ground level would be an example of a ____________.



gradient

---

31. Or, if you were to find another set of stairs on the other side of you and walk down them, this would be an example of a ____________ in either direction.

gradient

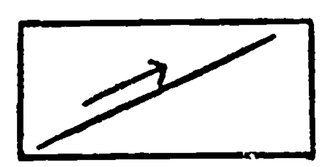
---

32. This word, gradient, is not used in our language meaning actually "to step or to walk". The meaning is close, however. It means a slope, something ascending or descending gradually. A change in something at a gradual rate would be an example of a ____________.

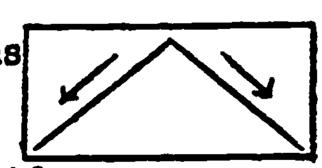
gradient

---

33. A gradient, then, can be in one direction



or two directions



as long as the change is gradual or at uniform ____________.

rate or speed or slope (any of these)

---

34. In the figure at the right do you find an example of a gradient? Explain. ____________

No, the change is abrupt and not gradual.

---

35. The pH range shows gradual differences or changes and this is an example of a gradient. Refer back to frame 23. The gradual change from acidity to alkalinity would be an example of a ____________.

gradient

gradient

36. There is a decreasing annual temperature from the equator to the north pole. This gradual change in temperature represents a ______.

gradient

37. Going west in the United States from the Atlantic Coast to the Rocky Mountains, there is decreasing annual rainfall. This gradual difference in annual rainfall represents a ______.

38. INFORMATION ITEM ONLY - NO WRITTEN RESPONSE REQUIRED

In order to perform this experiment we will need to know how to measure correctly. One of the basic features of observation is measurement. If we do not measure precisely or correctly, then our experiment is faulty and of limited value. Scientists use the Metric System for measuring since all the units can be converted into other units by multiples of ten. The next several frames are concerned with the units of the Mëtric System.

100

39. The fundamental length unit in the Metric System is the standard meter (m). It is slightly longer than the yard in the English System—39.37 inches to be exact. The meter can then be divided into centimeters. "Centi" means "one hundred<u>th</u>" so there would be ______ centimeters (cm) in one meter.

1000

40. "Milli" means "one thousand<u>th</u>", so there would be ______ millimeters (mm) in a meter.

1000

41. In the English System 1760 yards equal a <u>mile</u>. In the Metric System a certain number of meters equal a <u>kilometer</u>. If "kilo" means a <u>thousand</u>, there would be ______ meters in a kilometer (km).

1000

42. The basic Metric standard of mass is the kilogram (kg). It equals 2.2 pounds. From what you have learned defining "kilo", a kilogram contains ______ grams (g). A gram is related to a kilogram somewhat as an ounce is related to a pound.

km^2

43. For area measurements in the Metric System we have square centimeters, square kilometers, etc. To write abbreviations for the area units we use exponents as a shorthand notation. Square centimeters is written cm^2; squared kilometers is written ______.

cm^3

44. Bulk or volume requires a cubical unit for measurement. Cubic feet is written, ft^3. Cubic centimeters is written ______________________.

---

liter

45. There is a special name given to a Metric unit of volume equal to 100 cm^3. It is called a liter (pronounced "leeter") and is just larger than a liquid quart. Going back to what we learned as a definition for "milli", meaning thousandth, a milliliter (ml) is 0.001 liter (l). Or 1000 milliliters equals one ______________.

1000

46. A cubic centimeter is, for all practical purposes, the <u>same</u> <u>volume</u> as a milliliter. If 1000 milliliters equal one liter, __________ cm^3 equal one liter. This is an important relationship to remember.

---

one

47. One cubic centimeter equals __________ milliliter.

---

ten
meter
yard
0.01
0.001, 1000

48. Now let's review the discussion on the Metric System. All the units in the Metric System can be converted into other units by multiples of (1) ________. The length unit is the (2) __________. It is slightly longer than the (3) __________, in the English System. A centimeter is (4) __________ meter. A millimeter is (5) __________ meter. A kilometer equals (6) ________ meters.

kilogram
1000

The Metric unit of mass is the (7) ________________, which represents (8) ________________ grams.

length; cm^2 or km^2
cm^3

liter; one
0.001

The metric units for area and volume are based on the (9) __________ units. Area is expressed in (10) ________: volume is expressed as (11) __________. The special name given to a Metric unit of volume equal to 1000 cm^3 is a (12) ______________. One cm^3 is equal to (13) ________ milliliter. A milliliter equals (14) __________ liter.

---

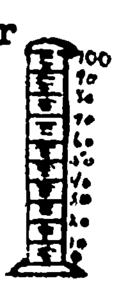
acid

49. In this experiment, solutions of sodium hydroxide (NaOH) and hydrochloric acid (HCl) will be used. NaOH is a base or alkaline and HCl will be used for an ______________ environment.

---

1 to 100

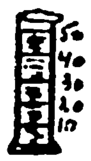
50. A graduate cylinder will be needed to measure your solution. By inspecting the figure at the right you could measure from ________ to ________ milliliters of a liquid with that size graduate cylinder.



---

1 to 50

51. By inspecting the figure at the right, you could measure _______ to _______ millimeters of liquid with a graduate cylinder of that size.



---

acidity, alkalinity

52. You will need pH paper ranging from 1 to 11. It is used to test your solution to see that it has the proper pH environment. The pH scale shows gradual changes from _______________ to _______________.

---

53. INFORMATION ITEM - NO WRITTEN RESPONSE REQUIRED.

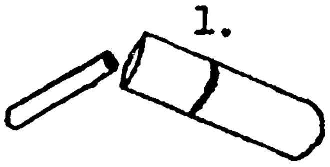
Now we are ready for the laboratory experiment. You will notice the materials and equipment are placed in the room for you. Look for a sign which has the title "A Gradient: The Effect of pH on Yeast Activity". There you will find the equipment and supplies needed, each numbered according to the following list. The items numbered in the list correspond with the numbers on the materials and equipment which you see.

1. Test tubes - Large - 5
2. Test tubes - Small - 5
3. Test tube rack
4. pH paper
5. NaOH solution
6. HCl solution
7. Yeast-sugar solution
8. Graduate cylinder
9. Small beaker
10. Millimeter rule
11. Wax pencil for labelling test tubes
12. Stirrer

If there are fifteen minutes remaining in the period you may continue through frame 54. If there are thirty or more minutes remaining in the period you may have time to complete the entire experiment. Judge according to the pace at which you work. Please allow five minutes before the bell rings to begin putting supplies and equipment away with which you are working. When you hear the alarm clock ring, this is a signal to begin putting your equipment away. Find a place on the shelf along the door side to store your materials until tomorrow. Write your name on a piece of paper and put it with your equipment. If there are less than fifteen minutes remaining in the period, spend the time getting familiar with the procedure, what you are to do tomorrow, and review the frames which you have just finished.

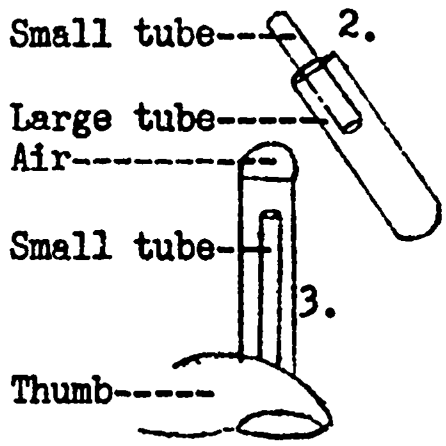
a. Practice manipulating the test tubes by measuring 30 ml of water in the graduate cylinder. Pour the 30 ml into a big test tube and then fill the small tube with water from the large tube. After you have filled the small tube with water, hold it up to the large tube at about the angle or

1.

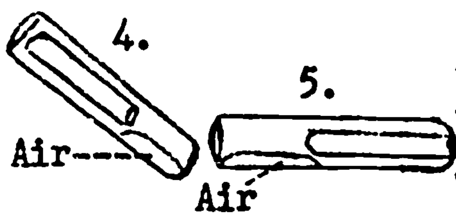


position you see in figure 1. at the left. Capsize or turn the small tube upside down quickly in the large tube so that it is completely submerged, open end down. Look at figures 1. and 2. carefully until you understand what has just been said.

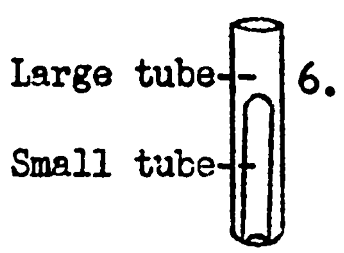
2.



b. Hold your thumb over the open end of the large tube and turn it upside down, so that all the air in either tube is collected in the bottom of the large tube. Study figure 3. at the left until you understand what has just been said.



c. Carefully turn the large tube upright in such a way that the bubble of air passes upward past the open end of the small tube without entering it. Study figures 4., 5., and 6. until you understand how to do it.



e. Practice until you obtain the desired results. Have your teacher check your results before you proceed further.

Yeast can carry on fermentation in an atmosphere without oxygen.

54. From what we have learned regarding yeast fermentation, why is it necessary to get all the air bubbles out?(Own words)

---

55. PROCEDURAL ITEM

a. Using the wax pencil number the five large test tubes 1, 5, 7, 9, and 11. This indicates you are going to set up pH 1, pH 5, pH 7, pH 9, and pH 11 environments. When you use the wax pencil do not press too hard. If a piece is broken off discard it in the waste can. DO NOT THROW IT ON THE FLOOR. If it breaks off or wears down, ask your instructor to see that more of the wax is exposed. Do not attempt it yourself.

b. Now put 150 ml of yeast-sugar solution in a beaker or small jar, using the graduate cylinder for measurement. If you have a 100 ml graduate cylinder, you will need to fill it once, empty the contents in your beaker and then fill it up to 50 ml to make a total of 150 ml of yeast-sugar solution. If you are using a 50 ml graduate cylinder, you will need to fill it three times to total 150 ml of yeast-sugar solution.

c. Put 30 ml of this solution into each of the five large test tubes. If you pour a measured amount into one test tube, you may simply pour the others to match it.

d. Next we want to arrive at a <u>gradient</u> of pH or acid-alkaline environments. Remember this will represent a gradual change from from one extreme to the other. Take the bottle of HCl and <u>carefully</u> put 15 drops of HCl in the test tube you

labelled "1". This will yield a highly acidic environment.

e. Put 2 drops of HCl in the test tube labelled "5".

f. Now take the bottle of NaOH and put 15 drops in the tube labelled "11".

g. Put 5 drops of NaOH in the test tube labelled "9".

h. Put 2 drops of NaOH in the test tube labelled "7".

i. Place a 6" strip of pH paper on a paper towel.

j. Now take a stirrer and stir the contents of test tube "1". Shake off any excess solution. If you don't your 6" strip of pH paper will absorb too much of the solution. The color will spread like a blotter. Put the tip of the stirrer on a small portion of the strip of pH paper. Check to see that the change of color of the paper matches the pH code color. The pH code color is indicated on the pH paper container. Study the color chart on the container. Notice that there are numbers "1" to "12" on the container. This is the pH range that can be tested with this pH paper. Now notice that a slightly different color is associated with each number. You will be interested in the colors for 1, 5, 7, 9, and 11. Each of your respective environments should change the pH paper each of these five colors on the color chart. If your test tube "1" matches the color indicated for "1" on the color chart, you need not add any more acid or base. If your test color is not correct, add <u>one</u> drop at a time of either HCl or NaOH, depending upon whether your solution needs to be more acidic or more basic. If for example, your "7" is dark blue, it is too basic. You need to start adding a drop at a time of HCl. Then test after adding each drop. An acid and base can neutralize each other.

k. Test each of the remaining solutions in the same way, remembering to rinse the stirrer each time you proceed to a different test tube. If you are careless about this procedure, your results may not be correct because solution is transferred from one test tube to another.

l. The next step is tricky as you probably discovered from practicing with water. Fill the small tubes with liquid from each of the large tubes, one at a time.

m. Capsize the small tube quickly in the large tube so that it is completely submerged, open end down.

n. Hold your thumb over the open end of the large tube and turn it upside down, so that all of the air in either tube is collected in the bottom (now turned upward) of the large tube.

o. Carefully turn the large tube upright in such a way that the bubble of air passes upward past the open end of the small tube without entering it. Your yeast are now ready to carry on activity.

p. Place the test tubes upright in the test tube rack. Leave them at room temperature for 24 hours. You must have the small test tube submerged within the large test tube before you leave them or you will not be able to collect the carbon dioxide that is given off.

q. Clean all equipment which you have used at this time, and put it back in place.

GO ON TO THE NEXT PAGE, page 10.

arbon
lioxide
·crose

56. At the end of the 24-hour period, if your results are correct, you can measure with a millimeter rule the amounts of gas produced in each tube. The gas produced is ________ ____________, and end product of the breakdown of the carbohydrate, ______________________.

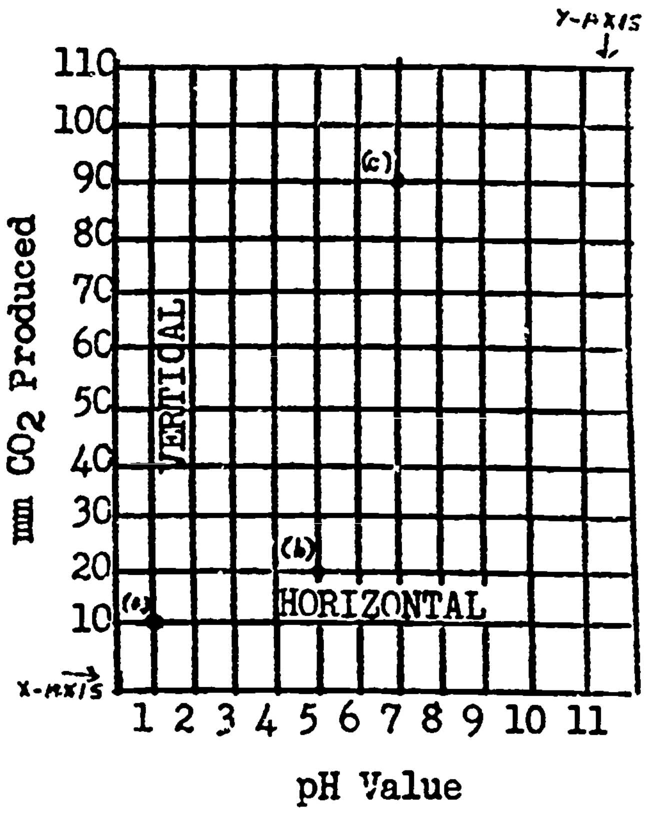
ctivity or
ermentation

57. The amount of gas produced is an index or indication of the amount of yeast ____________ which has occurred.

58. INFORMATION ITEM - NO RESPONSE REQUIRED

There is nothing more you can do with your experiment until 24 hours have passed, enabling the yeast to metabolize or change the yeast-sugar solution into other products. However, when you do observe the results we want you to record these data you have experimentally collected on a graph. A graph is simple a diagram or picture symbolizing a system of interrelations. Something which is interrelated is also showing dependency, as was mentioned previously.

59. On a line graph, data are properly placed and then connected by lines. One system of information is shown in relation to another. With our data we want to plot the amount of gas produced in relation to the pH environment of the yeast. We choose one system of information to place along the x-axis, the horizontal axis, and the other information is plotted along the y-axis, or vertical line. See the figure at the right. Now suppose in our pH 1 environment tomorrow we find 10mm of gas produced. We would find the 10 along the y-axis and the 1 along the x-axis, and place a dot there. See (a) in the figure. If we found 20mm of gas produced in a pH of 5 we would find it at (b) in the figure. Locate (c) on the figure. It is interpreted to mean that in a pH of __________, yeast generally produce, at room temperature ________mm of CO_2.



)

60. PROCEDURAL ITEM

a. Be sure to label your graph properly as you see in the figure, putting "mm of CO_2 produced" along the y-axis and the "pH Value" along the x-axis. After

you have measured the millimeters of gas produced and know the range of millimeters you'll need, then mark off along the y-axis (Look back at the figure in frame 59.)

b. If your greatest production is 80mm and your lowest 0mm, then you would need to mark off o through 80 along the y-axis. Study the figure in frame 59.

c. Keep all the intervals or spaces between numerals the same. Put your numerals right <u>at the lines</u> on the graph paper. Study this on the figure of frame 59.

---

11 61. Along the x-axis your range of pH will need to be from 1 to ____________________

---

62. Now put this exercise aside. When you come to class the next science period, begin with frame 63.

---

63. PROCEDURAL ITEM - NO WRITTEN RESPONSE NECESSARY

a. Begin by observing the yeast activity, evidenced by the production of CO_2. The CO_2 should have collected in the small test tube. Remember carbon dioxide is a gas, so all you will see is that the solution, which was in the small tube, has been displaced.

b. Using your millimeter rule, measure as accurately as possible to the nearest millimeter, the carbon dioxide produced in each tube. Examine your millimeter rule carefully. Notice the number "15". This means 15 centimeters. Since there are 10 millimeters in one centimeter, 15 centimeters equal 150 millimeters. Place your millimeter rule along side the small tube having carbon dioxide in it. <u>Do not remove</u> the small tube having carbon dioxide before you measure. Place the beginning of the millimeter rule beside the beginning of the CO_2 production. Where the CO_2 production ends, read across to the point on your millimeter rule.

c. After you have measured each one, and recorded the data along the left margin of this sheet of paper, then plot your information on a piece of graph paper. You will find a piece of graph paper on the teacher's desk. Refer back to frames 58, 59, and 60 if you need to review instructions for graphing. <u>Do not</u> ask for help without studying thoroughly.

d. At this time, empty the contents of your test tubes, and wash them thoroughly. Find a test tube brush near the sinks to aid you. After you have cleaned them, turn the test tubes upside down in your rack, and place them back where you first found them.

e. From the data you have collected in your experimentation, try to answer questions found in frames 64 through 68 in your own words.

Your answer will depend upon *your* results. Usually the optimum pH is from 5 to 7.

64. What is the optimum (meaning "best) pH for yeast activity at room temperature? ____________________

65. Does the extent of yeast activity in the series of tubes constitute a gradient? ____________________

66. If your yeast activity has constituted a gradient, how

(GO ON TO THE NEXT PAGE, page 12.)

Answer depends upon results

would you describe it? ____________________

____

____

____

The rate of increase or decrease in events of nature; a gradual change of events

67. Define gradient. ____________________

____

____

____

There is a gradual change in the amount of CO_2 produced as one proceeds from much acidity to less, and from much alkalinity to less.

68. What is the relationship of your millimeters of gas produced to the pH gradient? ____________________

____

____

____

FURTHER INVESTIGATIONS

69. When you have determined the optimum pH for the activity of yeast, you may wish to investigate the relationship of yeast activity to other gradients. When you find that time allows, maintain the optimum pH, as you have determined it, and set up a gradient of nutrition using varying concentrations of sugar as a food source.

In this experiment you would be determining if varying concentrations of sugar would make any difference in the yeast activity instead of varying pHs. In your former experiment the sugar was kept constant, while the pH was varied. Now you may keep the pH constant, (at the optimum or best pH) and vary the amounts of sugar. A yeast solution is available if you plan to carry out this experiment. Then using what you have learned in the former experiment be on your own from this point. Remember! Be a true scientist—be accurate; keep record of all that you do; measure precisely.

____

70. A gradient of salinity (degree of saltiness) using varying solutions of table salt (NaCl) and optimum pH may be used to determine yeast activity. Be sure to start with very dilute solutions. Anything diluted is mixed with water or another liquid to diminish the strength of a solution.

____

71. A gradient of chlorination, using varying dilutions (water mixed with a liquid) of commercial Clorox as a chlorine source may be used to demonstrate a gradient of yeast activity. Be sure to start with very dilute solutions.

____

72. If you persue the experiment mentioned in frames 68 and 69, determine the killing point of the microorganisms.

____

73. Can you suggest how this observation is related to purification of water supplies? ________________________

---

74. Your original experiment will produce measurable results more quickly if you use heavier concentrations of yeast to seed the culture. A culture is the growth of microorganisms in a specially prepared nourishing substance. See if you can get measurable results in a single class period in this way. Try a gradient of yeast concentrations at the optimum pH. Be sure to mention time on your graph.

---

75. Your yeast will grow, as well as show activity at any particular pH if you add a bouillon cube (made from beef) to the 100 ml. of yeast-sugar solution. This will furnish some nitrogen for the yeast to utilize in growth. You may wish to experiment adding nitrogen. Be sure you mention yeast-sugar-nitrogen solution on your graph.

---

76. The natural world is full of gradients which interact with one another. Perhaps you can think of other variations for experimentation with yeast activity you would like to attempt. There are copies of American Biology Teacher in the room for your use. You may wish to read "Experiences with Bacteria in High School Biology," Sister M. Paulinus, O.P., American Biology Teacher, Volume 22, Number 6, pages 325-332, June 1960, and see if you have had any similar experiences in collecting your data regarding microorganisms.

---

77. If you have time remaining in the period begin on the next programmed lesson. File this lesson in a safe place so that you may review it later.

A GRADIENT FOR THE SEPARATION OF CHEMICAL SUBSTANCES:

PAPER CHROMATOGRAPHY

matter	1. The ordinary things which we see and use in daily life are forms of matter. Anything that occupies space and has weight is matter. The air we breathe, the water we drink, and the foods we eat are kinds of ________.
matter	2. There are thousands of kinds of things and each thing represents a form of ________.
matter	3. Air, water, food, iron, gold, wool, soil, and plastics are all familiar examples of things we see and use in daily life and are kinds of ________.
substance	4. The term substance is commonly applied to any material thing, whether the thing consists of a single kind of matter or a mixture of several kinds of matter. Another word for matter, then, is ________.
substance	5. Sugar would be considered a substance consisting of a single kind of matter. Oxygen is also a single kind of matter and would be considered a ________.
several kinds of matter	6. Sugar and other ingredients making up a chocolate cake would be a mixture of several kinds of matter. Air, containing oxygen and other matter would be a mixture of ________ ________ ________ ________.
substance	7. Any material thing whether consisting of a single kind of matter or a mixture of different kinds of matter is called a ________.
pure	8. The term pure substance is applied to a single kind of matter. This means its composition, (of what it is made) never changes. Sugar is a single kind of matter; therefore it is a ________ substance.
pure	9. Oxygen is a single kind of matter. Oxygen is a ________ substance.
solution	10. Mix water with sugar and a mixture of different kinds of matter results. One type of mixture of different kinds of matter is called a solution. A mixture of sugar and water is called a ________.

pure substances and solutions or mixtures

11. The two classes or types of matter we have discussed are ________ ________ and ________.

single kind

12. A pure substance consists of a ________ ________ of matter.

several kinds

13. A mixture consists of ________ ________ of matter.

molecule

14. All matter is composed of <u>molecules</u>. A molecule is the smallest particle of a substance that still retains the characteristics of the substance. The smallest particle of water would be a ________ of water.

are no longer retained or they change

15. Molecules are made up of <u>atoms</u> which cling tightly to each other, if the characteristics of a substance are retained. Should the atoms become separated, then characteristics of that substance ________ (Own words)

water

16. Water is composed of two atoms of hydrogen and one atom of oxygen. Should the atoms of hydrogen be separated from the atom of oxygen, we no longer have ________.

compound

17. A <u>compound</u> is composed of molecules that are all alike. Every molecule in a drop of water is composed of two atoms of hydrogen and one atom of oxygen. Water could be called a ________.

compound

18. Every sugar molecule is composed of exact numbers of oxygen, hydrogen, and carbon atoms. Sugar can also be called a ________.

alike

19. All molecules in a compound are exactly ________ ________.

hydrogen
oxygen

20. Each molecule of a compound contains at least two kinds of <u>atoms</u>. An atom is the smallest particle making up matter. The kinds of atoms in water are ________ and ________.

compound

21. Suppose we break up the water molecule into hydrogen and oxygen atoms. We no longer have a molecule with two kinds of atoms; therefore, we no longer have a ________.

22. If we have a molecule with only one kind of atom we have an <u>element</u>. The oxygen molecule consists of two atoms

element	of oxygen. Oxygen is called a (an) ________________.
type or kind element	23. Hydrogen molecules are made up of two atoms of hydrogen. Both atoms are the same ____________, so hydrogen is also an ________________.
compound	24. If we allow two atoms of hydrogen and one atom of oxygen to combine we no longer have two elements but a ________________.
two	25. A compound is made up of molecules containing <u>not less than</u> ________________ kinds of atoms.
element	26. Iron, copper, gold, silver, and carbon are all elements since the molecules of each are composed of one kind of atom only. A chlorine molecule is composed of two chlorine atoms. Is chlorine an element or compound? ________________
alike or the same	27. An element is a substance which cannot be decomposed and made to yield two different kinds of matter by ordinary chemical means. This is because its atoms are all ________.
single kinds of matter	28. Both elements and compounds are classed as <u>pure</u> substances. Remember a pure substance consists of a single kind of matter. Elements and compounds consist of ________ ________ ________ ________.
alike or the same	29. Elements and compounds are considered single kinds of matter because their <u>molecules</u> (not atoms) are all ________.
pure	30. Many forms of matter are composed of molecules that are <u>not</u> all alike. Our earth is made up of many compounds and elements. Therefore the earth could <u>not</u> be considered a ________________ substance.
mixture	31. Remember a mixture is composed of two or more different kinds of matter. The earth is composed of more than a single kind of matter, of more than one kind of molecule, so it is a ________________.
mixtures pure substances	32. Let's review what you have learned thus far by referring to the figure at the right for frames 32-42. The two types of matter are ________________ and ________ ________.

Matter
- Mixtures
- Pure Substances
  - Compounds (two or more kinds of atoms in a molecule)
  - Elements (one kind of atom in a molecule)

elements compounds (any order)	33. Pure substances include ____________ and ____________.
more than one kind of matter or more than one kind of molecule	34. A mixture is composed of ____________ (Own Words)
one kind of matter or one kind of molecule	35. A pure substance consists of only ____________ (Own Words)
elements, compounds (any order)	36. Both ____________ and ____________ are pure substances.
alike or the same	37. Both elements and compounds are pure substances because their molecules are ____________ (Own words).
the characteristics of a substance	38. A molecule is the smallest particle of a substance that still retains ____________ (Own words).
atoms	39. A molecule is made up of ____________ which cling tightly to each other.
element	40. If the atoms in a molecule are all one kind, the substance is called an ____________.
compound	41. If the atoms in a molecule consist of two or more kinds of atoms, the substance is called a ____________.
weight	42. Matter is anything occupying space and having ____________.
substance	43. Another word for matter is ____________.
compounds	44. <u>Chemistry</u> is a science which deals with the composition and characteristics or properties of substances, and their reactions. Chemists, then, would work with mixtures, elements, and ____________.
color	45. One of the most valuable methods which chemists have for separating small amounts of pure substances from a mixture of chemical compounds is that of <u>chromatography</u>. Chromatography is a word made from two Greek words, <u>chromatos</u> meaning "color", and <u>graphos</u> meaning "write". Chromatography then means ____________ writing.

paper	46. In our experiment we will experiment with <u>paper chromatography</u>. When you have completed the experiment, you can expect to see "color writing" on ________________.
moisture	47. The paper has to be a special kind, a porous (full of tiny holes) paper so it can absorb moisture. <u>Filter paper</u> is used in our experiment to absorb __________________.
solvent	48. A small amount of the solution (mixture) that we want to separate, is placed on one end of a strip of filter paper. A liquid (water or other) which will dissolve the compounds in the mixture is allowed to creep up the paper. This liquid is called a solvent. Water could be used as a ______________________________.
paper	49. As the solvent ascends up the filter paper through the spot of mixture placed on the paper, the pigments move with it. Pigments are coloring matter and can be separated by means of ______________ chromatography.
weakly held	50. The pigments move with the solvent for a certain distance, but not indefinitely because the pigments are held by the paper, some strongly, some weakly. Which pigments do you think would travel or "write" color the farthest distance, those which are strongly held by the paper or weakly held?______________________________.
components	51. With each <u>component</u> traveling at its own rate, the individual components become separated. A component is one of the parts of a whole. The compounds with different pigments could be called __________________________.
components	52. Any compound or mixture is made up of components. If we separated water into hydrogen and oxygen, hydrogen and oxygen would be considered ___________________ of water.
substance	53. When the solvent (water or other) dries, each component is left in pure form apart from the others so that each now makes a separate spot on the paper. Each of these components would be known as a pure __________________.
paper	54. Now we can define chromatography more completely. It is a method of <u>analysis</u> in which the flow of a solvent promotes the separation of substances in a porous medium. The porous medium in our experiment is filter __________.
	55. <u>Analysis</u> means a separating or breaking up of any whole into <u>its parts</u>. We shall be analyzing a mixture to

its parts or pure substances

separate it into ______________ ______________.

---

compounds
elements
(any order)

56. The importance of chromatography lies primarily in its use as a tool for analysis. Chemists are interested in analyzing or separating mixtures, ______________ and ______________.

---

amount

57. In chemical analysis, each of the separated components may be removed and its <u>amount</u> accurately determined. This means that not only can the components be identified but the ______________ of the component can be determined by the method of chromatography.

---

58. INFORMATION ITEM - NO WRITTEN RESPONSE REQUIRED

Now we are ready for the laboratory experiment. You will notice the materials and equipment are placed in the work area for you. Check over the following list and make sure you have these materials and equipment with which to work. The items numbered in the list correspond with the numbers on the materials and equipment which you see. Take these items to an area designated for you to work.

1. Two glass jars
2. Two aluminum foil jar covers
3. Six strips filter paper
4. Six flat wooden toothpicks
5. Two paper clips
6. Food coloring (Start with any color you desire.)
7. Washable ink (Start with any color you desire.)
8. Wax pencil

---

59. PROCEDURAL ITEM - NO RESPONSE REQUIRED

a. Be a good judge of the amount of time left in this period. You should have approximately twenty minutes to get a good start on this experiment. If there are less than twenty minutes remaining, become familiar with the items you will be using and with the procedure so that you can begin immediately tomorrow. Then spend any remaining time reviewing the frames you just finished. This will help you prepare for a final test on all the lessons. If you have time for beginning the experiment then proceed with b.

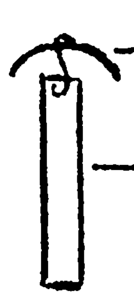
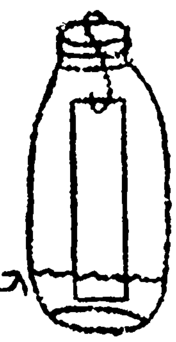


figure c.

b. Bend a paper clip to form a small hook which can be fastened to the aluminum foil cover.

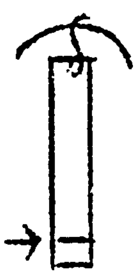
c. Suspend the strip of filter paper from the aluminum jar cover by attaching the upper portion of it to the hook. (See figure c. at the left.)



Water Line

d. Place the cover over the jar with the filter paper attached and mark a water line with a wax pencil. THE WATER SHOULD NOT COME IN CONTACT WITH THE SOLUTION ON THE PAPER. (See figure d. at the left.) Place a mark so that the tip of the filter paper is submerged in the water. This is very important. If you do moisten the strip of filter paper above your ink or food coloring solution, the experiment will not turn out well.

e. Remove the jar cover, hook, and filter paper.



Solution

Filter Paper

f. Dip the small end of a wooden toothpick one-third to one half its length in the solution (ink or food coloring) to be tested, and lay the narrowest dimension of it flatly across the strip of filter paper about three-fourths of an inch above the lower end of the strip, making a narrow band completely across the strip. (See figure f. to the left.) It is important not to apply too much of the solution. Too heavy applications will result in poor separation of the components.

g. Put a sufficient amount of water into the jar to allow the lower end of the filter paper to extend into the water. (Refer to figure d. at the left.)

h. Place the jar cover carrying the strip of filter paper in the neck of the jar very carefully. Check again to see that only the tip of your paper is submerged.

i. Allow enough time for the water to migrate up through the filter paper to the top of the paper. When the pigments are located near the top, you may remove the filter paper.

j. Remove the filter paper and put it aside to dry.

k. While you are waiting for your filter paper to dry, try this same process with a different food coloring, or a different color of ink. Try as many different solutions as you have time for. Be sure, however, that you allow five minutes before the bell rings to clean your work area, put materials back in place, and be ready for your next class on time.

---

60. Observe what has happened on your dried filter paper. If you were plotting your results on graph paper, can you determine what the relationship of the separated components would be to the distance travelled from the solvent (water) front? ____________________

Each component should have travelled a farther distance than the one before, forming a slope on a graph.

Yes, because it forms a slope, gradually increasing in a greater distance travelled.

61. Does this type of relationship remind you of a gradient?
Explain.

It should be if each of your components travelled farther than the others.

62. Do you think paper chromatography is explainable in terms of a gradient?

A gradient of diluted concentrations of the test materials can be prepared, and the separated component is then matched with the proper dilution. Knowing the amount in the different concentrations enables a chemist to know how much is in his separated component.

63. There are several methods chemists have for determining the amounts of each component in a mixture, separated by chromatographic methods. There is a way to do this without resorting to detailed chemical analysis. Can you think of a way this might be accomplished? Explain.

64. At this time please take a piece of paper and write down ten questions which you can raise concerning the idea of a gradient or what you have been studying in this lesson. Several questions probably have already arisen in your mind as you worked with these two experiments. They should not be questions requiring only a definition, but such as the following:

Does every event show a gradient?
How would you go about studying growth gradients in human beings?
Why do happenings in nature usually form a gradient?

When you have written ten questions, give them to your teacher. This work could be done as a homework assignment.

65. FURTHER INVESTIGATIONS

Some substances are soluble in alcohol as readily as in water or more so. Others are not. Try dissolving food coloring or ink in commercial rubbing alcohol. How well does this work? Try the paper chromatographic technique, using alcohol wherever water is indicated. What results do you get? Explain any differences in results.

66. The natural world is full of gradients, of things which change gradually. In your experiment you probably found that compounds gradually travel on filter paper farther than the one before.

The filter paper has more of an attraction for some than it does others, and absorbs and holds them more strongly. Thus, a gradient is demonstrated by how strongly a component is attracted by filter paper.

You might be interested in knowing how long chromatography has been in use. There are several methods other than paper that can be used. Are you curious to know what extent chromatography is used in modern chemistry? Think of ways you might go about finding answers to these questions. There are references available to you in this room.

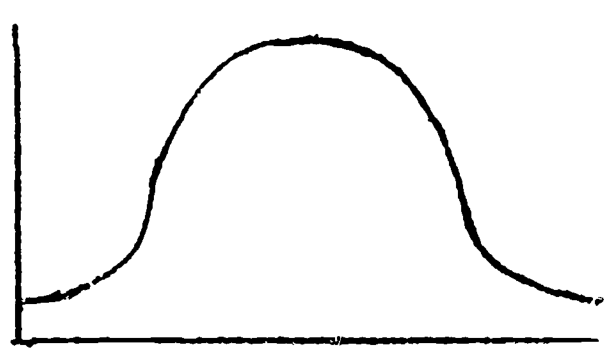
---

67. If you have time remaining in the period begin on the next programmed lesson. File this lesson in a safe place so that you may review it later.

NORMAL DISTRIBUTION CURVES DESCRIBE VARIATION IN NATURE

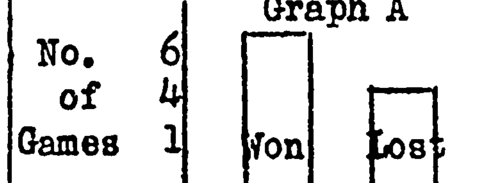
Section________ Name______________________________

alike	1. There is variation in everything. Offspring are never exactly like the parents, plant or animal. For example, no two human beings have exactly the same fingerprints, plus other differences. No human beings are exactly __________.
alike	2. No two leaves are exactly alike in the plant kingdom, and plants not bearing leaves differ from other plants in some way. No two plants are exactly ________________.
norm	3. In the natural world, related happenings tend to differ in a certain pattern around a norm. The norm is the average, the typical. The typical seventh grader is 12.5 years of age. The age of 12.5 years would be called the __________ for the age of a seventh grader.
norm	4. The typical height for a 12 year old girl is 60 inches. A 12 year old girl who has a height of 60 inches can be described as being at the _________ height for her age.
average, typical (any order)	5. In any average there must be as many below the norm as above. There are as many seventh graders older than 12.5 years as younger than 12.5 years. The norm is just the ______________ or the ______________.
below	6. Likewise there would be as many 12 year olds above 60 inches in height as ______________ 60 inches in height.
pattern	7. Related happenings such as test scores, weights, heights, intelligence scores, the sizes of beans of a particular sort, temperature readings, etc. usually form a certain pattern around the norm. The length of leaves on a tree will form a certain ____________________ around the norm.
events or happenings (either answer)	8. The pattern will usually look like a "bell-shaped curve". This is also called a normal curve, meaning this is the typical pattern that normally occurs. This is true only for related ______________.
four	9. A good way to show how related events happen is to use a graph. For example, Graph A shows that the Giants lost _____ games in 1950.



Bell-shaped or normal curve

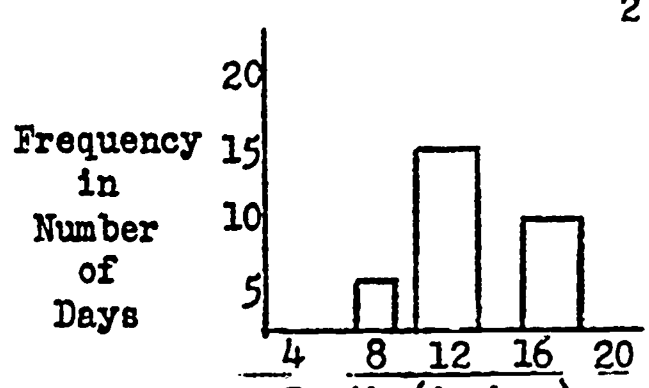
Graph A



1950 Record

frequency distribution

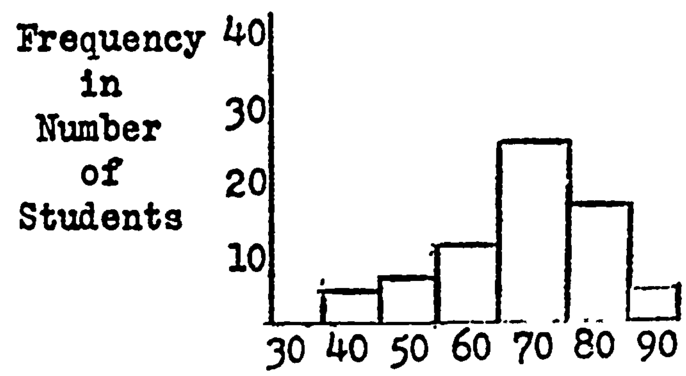
10. The data or information recorded on a graph can be summarized with a frequency distribution. Since Graph B shows how frequently (how often) different amounts of snowfall occurred, it would be called a ____________ ____________.



Graph B: Snowfall in 1956

5

11. The frequency distribution in Graph C shows the number of students making different scores on a test. The score of 60 occurred 14 times and a score of 90 occurred ________ times.



Graph C:

---

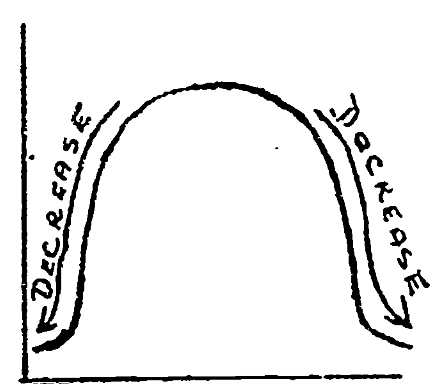
central or middle (either answer)

12. In a frequency distribution, then we are summarizing how often or how frequently events occur. Putting this information on a graph often forms a bell-shaped curve. If there are half as many events below the norm as above, the norm would be the ______________ point on the x-axis of the graph.

---

bell-shaped

13. In a normal distribution some of the data (information) will "pile up" near the norm, the others decrease in frequency on each side of the norm. This makes Graph D look like a ______________ curve. Actually events in nature never form a perfect, bell-shaped curve. They only come close to it or approximate it.

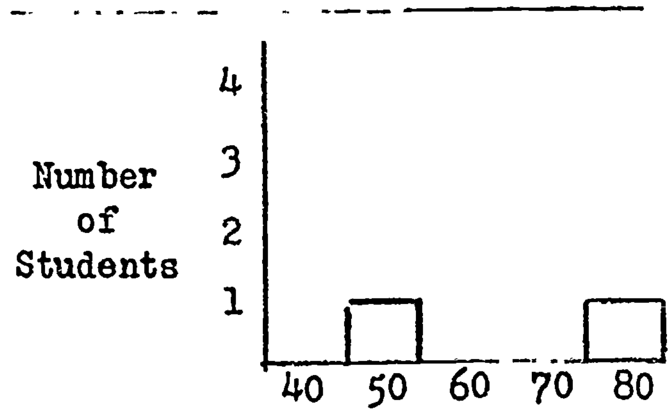


Graph D: Bell-shaped curve

---

no

14. For events to exhibit "normal curve" behavior, a sufficiently large and representative sample of data is necessary. Suppose we used only two test scores in a distribution (Graph E). Would this represent a normal curve? ______________



Graph E:

population	15. In order to understand what a representative sample is we need to know what a <u>population</u> is. A <u>population</u> is any group of people or objects which are alike in one or more ways. Example: The New York Yankees are a population, since they are all baseball players and all play for New York. Also: Wynken, Blynken, and Nod are a __________ since they all sailed off in a wooden shoe.
population one	16. All Atlanta lawyers can be called a __________ since they are alike in ________ or more ways.
sample, population	17. If we draw from a population any number of cases <u>less</u> than the total number in that population, we have a SAMPLE. Wynken and Blynken are a sample from the population of Wynken, Blynken, and Nod. Lincoln, Washington, Jefferson, and Wilson form a population. Washington and Jefferson make up a __________ of that __________.
population sample	18. All the voters in the United States can be called a __________ of which all the female voters in the United States make up a __________.
more	19. A population is made up of (more/less) __________ cases than is a sample from that population.
A, B	20. A. Jim, Jane, Tom. B. Tom, Jane, Bill, Jim. Which is the sample? ______ Which is the population?______
characteristic measured	21. All populations have certain characteristics which can be counted or measured. Example: All Swiss basketball players have height, which is a characteristic which can be measured. All professional football players have <u>weight</u>, which is a __________ which can be __________.
set	22. When we count or measure a characteristic of a population, we get a SET of numbers or measures. Example: Measuring the weight of the Tech backfield might produce this set of measures: 168 lbs., 193 lbs., 184 lbs., and 201 lbs. These measures make up a ______ of measures.
set	23. A <u>set</u> is a collection of numbers or measures. It can also be a collection of any kind of objects. Example: These numbers (3, 7, 21) can be called a <u>set</u>. Also: The measures (5 ft., 7 ft., 84 ft.) can be called a ______.
set	24. The measures (3 seconds, 9 seconds, 4 seconds) form a __________.

subset

25. A SUBSET is any portion or part of a set. Example: (3, 4) is a subset of (1, 2, 3, 4). Also: (8, 2)is a ______________ of (8, 3, 2, 9, 4, 13, 200).

(9, 8, 6, 4)
(8, 9, 4, 6, 1)

26. Look at these numbers: (8, 9, 4, 6, 1) and (9, 8, 6,4). Which is the subset? __________ Which is the set? ______

No. Eight is not in the set.

27. Is (3, 8) a subset of (3, 7, 9)? __________ If not, why not? ______________________________

---

population
sample
subset
characteristics

28. Any group of people or objects alike in one or more ways is called a ______________. A number of cases less than the total population is called a __________. A portion or part of a set is called a ______________. All populations have certain ______________ which can be counted or measured.

---

sample
population

29. The same group of individuals or objects may make up a whole population, or just a sample of another population. Robinson Crusoe and Friday make up a ______________ of all fictional characters, but they make up the ______________ of the characters in the book Robinson Crusoe.

---

sample
population

30. The members of the Georgia football team make up a ______________ of all football players in the United States but they make up the ______________ of the Georgia team.

---

population

31. Often measuring a characteristic of a whole population takes too much time or money. In these cases we can sometimes get a good idea about the ______________ by taking a sample.

---

time
money
(any order)

32. Two reasons for measuring a sample rather than measuring a population are: To save ______________ and to save ______________.

No. It would be impossible to collect them. No, it would be very expensive.

33. In the experiment for this laboratory experience you will be measuring a sample of the lima bean population. Do you think it would be practical for you to measure every lima bean in the world? __________ Would the cost to buy them be reasonable and the time it would take you to measure each one? ______________

---

34. Suppose you have a population of ten basketball players and you want to get a representative sample of five players. One way is to write each name on a separate slip

representative or "fair"

of paper, mix them in a hat, and draw out five names. Since each player has an equal chance of being chosen, such a sample seems to be ________________.

---

population
sample

35. The method just described is one way to get representative samples. That is, we can write the name of each individual in the ________________ on slips of paper, mix them, and draw out a ____________ of whatever size we want.

---

sample
population
sample

36. To save time and money, we sometimes measure the individuals in a ____________, although we are mainly interested in the ________________ from which the ______________ is drawn.

---

population

37. A group of individuals or objects having one or more characteristics in common is called a ______________.

---

any number of cases less than the total number of cases in the population

38. What is a sample? (Own words) ________________

____

____

____

39. The main reason we want a sample to be representative is so that the measures we obtain will give a good estimate of the ________________ from which the sample was drawn.

population

---

samples

40. In your laboratory experience you will be measuring lima bean seeds in groups of ten from a pound of dry lima beans. We will consider the pound of limas a population; the groups of ten which you select will be different ________________________ of that population.

---

representative

41. Since beans have no names to be drawn from a hat like the basketball players, we merely select them at "random". This means you take the first ten poured out without carefully selecting them. A random sample should be a ____________________ sample.

---

sample

42. However, the size of the random sample must be large enough to be representative. This is difficult to determine but in general, when the continued addition to the sample of randomly chosen objects does not change the picture presented by the graph, the ______________ is representative.

---

43. As you measure the beans, you may have a certain length or width that occurs most frequently. The measure that

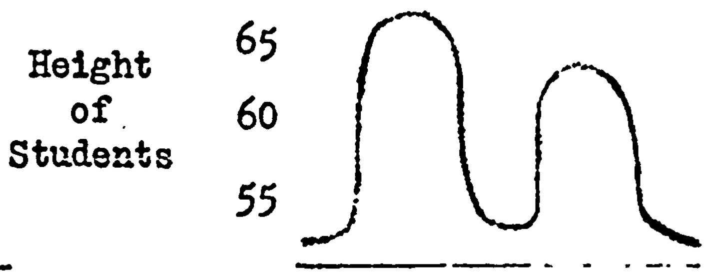
occurs most frequently is called the mode. If you had only one mode, then this would be the average, or typical measure and this is also called the ________.

norm

---

44. Sometimes, you may have a representative sample, but you still may not have a normal distribution. This is due to the operation of a warping factor or factors. To warp means to bend or distort out of shape, and away from the normal. Graph F and Graph G are both examples of warped distributions. A warped distribution could be a ________ sample, but not a ________ distribution.

Graph F



Graph G

representative

normal

---

45. Graph G above could represent the distribution of height in a seventh grade class of equal numbers of boys and girls. The average girl's height is 60 inches; the average boy's height is 65 inches. A mixed sex class would be acting as a ________ factor.

warping

---

46. If your class were given a test on which everyone scored zero, then these scores would not be representative of the distribution of ability within your class. The extremely difficult test would be a warping factor. A warping factor would be anything that (Own words) ________

changed or distorted the distribution of the sample from being representative or normal

---

47. To obtain the average weight of seventh graders, if we selected a sample of only those who weighed around 200 lbs., plotted their weights on a graph and found around 200 lbs. to be the norm for a seventh grader, this would constitute a ________ factor.

warping

---

48. A pair of dice tossed many times should give you a frequency distribution that looks like a normal curve for the numbers on the dice. However, if the dice were "loaded", made heavier on one side, this would throw off the normal amounts of times each number would turn up. "Loaded" dice would be a ________ ________.

warping factor

---

49. You will be measuring the greatest length of each bean with the millimeter rule. You recall a millimeter is 0.001 (1/1000) of a meter. The rule you will be using is 150

millimeters long. 150 millimeters is equal to about six
25 inches. One inch then equals ______________ millimeters.

---

50. A good way to summarize all your measurements is to use a <u>frequency tally</u>. This is done by placing a "<u>tally</u>" <u>mark</u> opposite the number representing a measure each time it occurs. For example, in Distribution A a measure of 3 occurs 2 times, so we put 2 tally marks opposite 3. A score of 4 occurs ______ times, so we put 3 ____________ ____________ opposite 4.

Distribution A:
3, 4, 3, 5, 2, 4, 4

Frequency Tally

2	/
3	//
4	///
5	/

three
tally
marks

---

51. Since tally marks are hard to estimate at a glance, we summarize our <u>frequency tally</u> with a <u>frequency table</u> as in B. Complete the table.

Figure A

Frequency Tally

Measure	Tally
10	/
20	//
30	卌
40	//

Figure B

Frequency Table

Measure	Frequency
10	1
20	2
30	______
40	______

5
2

---

frequency tally

52. A ____________ ____________ uses <u>tally marks</u> to show how frequently each measure of an event occurs in our sample.

---

53. A ____________ ____________ used <u>tally marks</u> to show how frequently each measure of an event occurs in our sample. (Duplication of frame 52)

frequency tally

---

frequency table

54. A ____________ ____________ uses <u>numbers</u> instead of tally marks to show the frequencies of such measurement.

---

55. Once you have a frequency table, you can, of course, quickly construct a frequency distribution such as:

Frequency Table

Measure (Length in mm)	Frequency (Number of Beans)
15 mm	20
16 mm	30
17 mm	40
18 mm	50
19 mm	40
20 mm	30
21 mm	20

56. PROCEDURAL ITEM - NO WRITTEN RESPONSE REQUIRED

Now we are ready for the laboratory experiment. You will notice the materials and equipment are placed in the room for you. Look for a sign entitled "Normal Distribution Curves Describe Variety in Nature". There you will find the equipment and supplies needed, each numbered according to the following list. Check over the list and make sure you have these materials with which to work. The items numbered in the list correspond with the numbers on the materials and equipment which you see.

1. Package of 100 dry lima beans of the same kind
2. Twelve paper cup containers
3. Magnifying glass
4. Millimeter rule
5. Glass marking (wax) pencil
6. Sheet graph paper (Pick this up later when you are ready to make a graph.)
7. One sheet of "Frequency Table" and "Frequency Tally" charts.
8. Simple balance or scales for measuring weight in grams and fractions of grams (for use <u>only</u> under FURTHER INVESTIGATIONS)

If there are fifteen minutes remaining in the period you may continue. Five minutes before the bell rings begin putting your supplies and equipment away. When you hear the alarm clock ring, this is a signal to begin putting your supplies away. Find a place on the shelf by the <u>window</u> to store your materials until tomorrow. Write your name on a piece of paper and put it with your equipment. If there are less than fifteen minutes remaining in the period, spend the time getting familiar with the procedure, what you are to do tomorrow, and review the frames which you have just finished.

---

57. Before beginning, study your millimeter rule. If yours is equal to a six-inch rule, you will find inches marked off where it says "inches". On the same side of the ruler you will find the word "metric". Notice the number "15". This
150 means there are 15 centimeters or ________ millimeters marked off on your ruler.

---

58. If you have a twelve-inch rule, then you will find
300 approximately 30 centimeters or __________ millimeters marked off on your ruler.

---

59. PROCEDURAL ITEM - NO WRITTEN RESPONSE REQUIRED

a. Measure the beans in groups of ten. Each "ten" should be selected at random, counted as they are selected from the container. <u>Now count out only ten.</u>

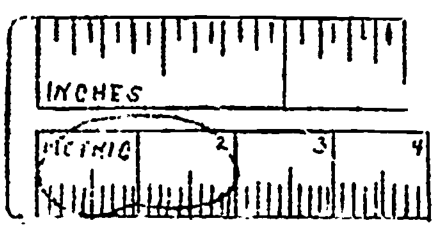
Frequency Tally

15mm	
16mm	|
17mm	|
18mm	
19mm	||
20mm	|||
21mm	||
22mm	
23mm	|
24mm	

b. Use one frequency tally chart for each group of ten beans measured. You will probably have a range somewhere between 15-25 mm. Try to keep your figures in numerical sequence in your frequency tally. (See the figure at the left.) You have 16 frequency charts on each sheet so this is enough for 16 groups of ten beans measured, if you need that many.

c. Place a tally mark beside the correct length each time you measure a bean.

d. Number your frequency tally charts 1, 2, 3, etc. as you measure additional groups of ten beans.



e. Now take a bean. Measure its greatest length with the millimeter rule. Determine the length to the nearest millimeter, using the magnifying glass for close distinction. You will soon develop a skill in doing this, such that the job will proceed relatively rapidly. Place the bean on the millimeter rule with one end of the bean at the beginning of the rule. Check the other end carefully, using the magnifying glass for greater accuracy. See the figure at the left.

f. When you have measured the first bean, file it in a paper container provided for you and mark the length on the container with your wax pencil. Do this with the second bean, if it is a different length, or file it in the same container if it is the same length. Continue until you have completed the first group of ten, setting up a new container every time you find a bean of a different length.

---

60. Do your containers which already have beans in them, form a continuous, numerical series (for example, 12mm, 13mm, 14mm, 15mm, 16mm, etc.), or is the series incomplete? If you don't have beans in a 14mm container, for example, but have some in the 13mm and 15mm containers, then you have a gap in your series at 14mm. That makes your series incomplete. ________

____

____

61. Have the beans begun to "pile up" in one or more of the containers? ________ What is this "piling up" of the frequency referred to? ________________

62. At what millimeter length is the mode or modes located in your series? ________________

____

63. Is there more than one mode? ________________

____

64. At this time, do you have a normal distribution among your ten beans; that is, do you have a piling up in the middle sizes with decreasing frequencies on either side? ________

____

65. PROCEDURAL ITEM - NO WRITTEN RESPONSE REQUIRED

a. Measure a second group of ten, proceeding as before. Keep a separate frequency tally for this second group, and each group.

b. When you have finished with your second group of ten, answer the following questions.

---

66. Do your containers form a continuous, numerical series after adding the second group of ten beans, or is the series incomplete? ____________

Answer depends upon results

67. Have the beans begun to "pile up" in one or more of the containers? ____________ What is this "piling up" of the frequency referred to? ____________

Answer depends mode or norm (either answer)

---

68. At what millimeter length is your mode or modes located now? ____________

Answer depends upon results

69. Is there more than one mode? ____________

Answer depends upon results

---

70. At this time do you have a normal distribution among your set of twenty beans? ____________

Answer depends upon results; it is not likely.

71. Are the answers to frames 66-70 the same as the answers to frames 60-64? ____________
If they are different, in what ways do they differ? ____________

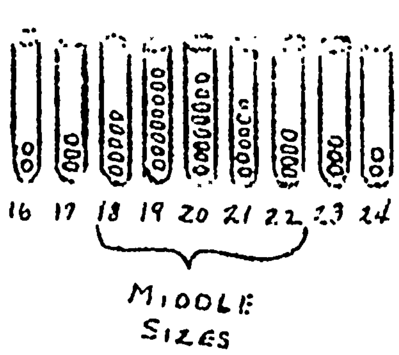
Answer depends upon results

---

72. PROCEDURAL ITEM - NO WRITTEN RESPONSE REQUIRED

a. Continue with a third group of ten, recording the answers as before. Remember to record your data in another frequency tally.

b. Follow with additional sets of "tens", until you approach a normal distribution. Try to continue measuring until no new size classes appear. In a normal distribution you will have fewer beans among the extreme sizes and many beans among the middle sizes. (See figure at the left.) Get a second package of 100 lima beans if you need them.



c. After you have completed all the length measurements you plan to investigate, answer the following questions.

---

73. How many "tens" did you have to measure before new size classes ceased to appear? ________ Determine this by checking which frequency tally was the last to have a new

Answer depends upon results

size class added.

Answer depends upon results

74. In which "tens" did you find the longest extremes of the population? __________

Answer depends upon results

75. How many "tens" did you have to measure before a definite mode became apparent? __________

Answer depends upon results

76. In which "tens" did you find the shortest extremes of the population? __________

Answer depends upon results

77. Recall the explanation of a representative sample. In general, one has a representative sample when the continued addition to the sample of randomly chosen objects does not change the picture presented by the graph. How many "tens" do you think it took to constitute a representative sample of the bean population? __________

---

78. PROCEDURAL ITEM - NO RESPONSE REQUIRED

a. Now count the total number of beans in each size class. For example if you have measured 100 lima beans, you should have set up 10 frequency tally charts. Suppose your shortest bean was 15mm. Count all the tally marks you have in all 10 frequency tally charts beside the 15mm. Do this for all lengths and record the total in a frequency table chart. You may just use the next frequency chart available after your last frequency tally of your last set of 10 beans. Refer to frame 55 if you forget what a frequency table looks like.

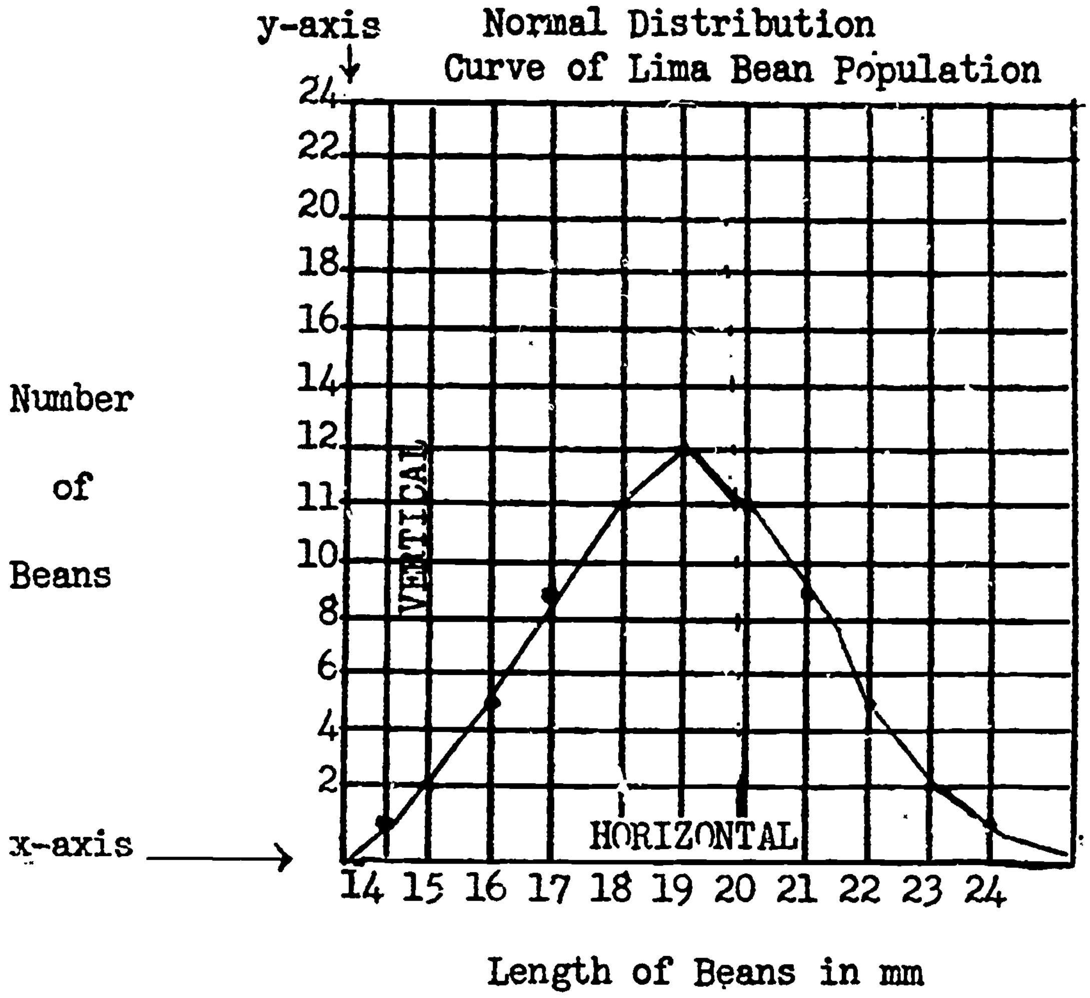
b. Record these data in a frequency table.

---

79. On a line graph, data are properly placed and then connected by lines. One system of information is shown in relation to another. With our data we want to plot the amount of the lima bean lengths in relation to how many beans measured that length. We choose one system of information to place along the x-axis, the horizontal axis, and the other information is plotted along the y-axis, or vertical line. See the figure on the top of the next page, page 11b. Now suppose you have a bean length of 14mm with only 1 out of 100 that have that length. Find 14 along the x-axis and 1 along the y-axis. Follow their lines until they meet. The data are plotted by placing a dot where their lines meet. See the figure at the top of the next page. Suppose you had 5 beans with 16mm lengths. The dot is placed where their lines meet.

normal curve or bell shaped curve

This is true for all the data. After all the data are plotted, then connect the dots by lines. Study the figure below. What type of curve would you say this graph represents?



a. Construct a graph showing the relationship of sizes to the numbers in each size class, as demonstrated on the graph at the tope of the page. You may group the number of beans in groups of twos or fives along the y-axis. Skip every other line along the x-axis and y-axis to make your graph larger.

b. Be sure you give your graph a title, and label the x-axis and the y-axis.

c. Put your name on it and keep it for future study.

80. To what extent does the graph showing your results approximate a normal curve? ______

Answer depends upon results

81. Do you think measurement of a larger sample would have given you a better curve? ______

Answer depends upon results

82. On the basis of your graph, do you wish to change your conclusions concerning what you thought was the size of a representative sample which you measured? ______

83. PROCEDURAL ITEM - NO WRITTEN RESPONSE REQUIRED

a. Check with your teacher to see if there is time for you to complete this section. Go to frame 97 if there is not time for you to complete this section.

b. Now go through this same experiment measuring the width of the beans instead of the length. Measure the beans in groups of ten. If you are using the same population of beans, and it would be best to use the same one, mix all your beans back together. Shake them well, and then draw ten at random. If you have turned your beans back in, select any package of 100.

c. Secure two sheets of frequency tally charts, and finish using the space left on your other frequency table chart sheet.

d. After measuring, file the beans in containers. Proceed as you did when measuring lengths; set up a separate container for each width. Clean off the old length figure and replace it by the width figure, if you have not already done so.

e. After you have finished the first set of ten, answer the set of the following questions.

Answer depends upon results

84. Do your containers form a continuous series or is the series incomplete? ______

Answer depends upon results

85. Have the beans begun to "pile up" in one of the containers? ______

Answer depends upon results

86. If so, where is the mode or modes located in your series? ______

Answer depends upon results

87. Is there more than one mode? ______

Answer depends upon results

88. At this time, do you have a normal distribution among your first set of ten beans? ______

89. PROCEDURAL ITEM - NO WRITTEN RESPONSE REQUIRED

a. Measure a second group of ten, proceeding as before.

As you go along, answer the set of questions mentally about each of the remaining sets of tens.

b. After you have completed all the width measurements you plan to investigate, answer the following questions.

Answer depends upon results

90. How many "tens" did you have to measure before new size classes ceased to appear? ____________

Answer depends upon results

91. How many "tens" did you have to measure before a definite mode became apparent? ____________

Answer depends upon results

92. In which "tens" did you find the longest extremes of the population? ____________

Answer depends upon results

93. In which "tens" did you find the shortest extremes of the population? ____________

Take the total number of extreme beans, place that number in the numerator, and put the total number of beans in your population in the denominator. Reduce the fraction.

94. How probable do you think it would be to pull a single bean at random from the population which would be representative of one of these extremes? ____________

95. How many "tens" do you think it took to constitute a representative sample of the bean population? ____________

---

96. PROCEDURAL ITEM - NO WRITTEN RESPONSE REQUIRED

a. Now count the total number of beans in each size class.

b. Record this information in a frequency table. Use these figures on your graph.

c. Construct a graph showing the relationship of sizes to the numbers in each size class.

d. Be sure you label the x-axis and the y-axis.

e. Give your graph a title.

f. Put your name on it and keep it for future study.

There is a gradual increase up to the mode and then a gradual decrease from the mode.

97. Try to answer how you think normal curves and gradients might be related. ____________

FURTHER INVESTIGATIONS

98. Combine the results obtained by other members of the class. Construct a similar graph showing results from the entire class. Do you get a better curve? If so, why? Is there a change in either the extremes of the population or the mode when the results of the entire class are combined?

---

99. As you measured the lima beans, did you notice any other kinds of variation other than the length and the width of the seed? How about the shape of the seed? If you were to weigh all of the seeds in each size class, or an adequate sample of them, do you think that the weight of each seed would bear the same relationship to their common length? Or would there be a normal curve of different weights within each size class? Try this and see, measuring weight in grams and fractions of grams.

---

100. What about other kinds of seeds? Nuts? Fruits? Leaves? What about various kinds of animals? What about humans? Do you think you could set up normal distribution curves for variation occurring in other living things? Try it in any case where you can obtain a sufficiently large population to constitute an adequate sample.

---

101. What about variation in non-living things in nature? What about variation in things that man has made?

It wouldn't be very likely that you would draw one often.

102. Recall the explanation of a representative sample. How probable do you think it would be to pull a single bean at random from the population which would be representative of one of these extreme sizes or lengths? ______________________

---

103. You are now finished with this experiment. Put the 100 lima beans back in the plastic bag. If you used more than 100 beans, please see that both bags are replaced for other students to use. The paper cups can be used again if you'll scratch out the writing which you have placed on them. Use your wax pencil to do this. Put all the other supplies you used back by their corresponding number.

---

104. If you have time remaining in the period begin on the next programmed lesson. File this lesson in a safe place so that you may review it later.

THE USE OF NORMAL CURVES IN DISTINGUISHING SPECIES

Section__________ Name______________________

exactly
one, more

1. All populations tend to vary and NO two are exactly alike. Recall that a population is any group of people or objects which are alike in one or more ways. Plant populations are not ______________ alike, but are alike in __________ or __________ ways.

---

arranges, divides
(any order)

2. Plant likenesses and differences enable a taxonomist to group plants. Taxonomy (tax on' o mee) is a branch of science and comes from the Greek word, taxis meaning ARRANGEMENT or DIVISION. A taxonomist is a scientist who ______________ or __________ plants into groups.

---

classify

3. To classify means to group objects according to some similar factor or factors common to each plant. Plant likenesses enable a taxonomist to __________ plants.

---

one
more

4. Arranging or dividing plants into groups means to classify them according to likenesses. For plants to be members of a particular group they must be alike in _____ or__________ ways.

---

arranging, dividing
classifying
(any order)

5. Taxonomy is a branch of science which deals with ______________ or ______________ or ______ __________ plants into groups.

---

one, more

6. The whole plant population on the earth is in one big group called a kingdom. In order for plants to be members of this kingdom, they must be alike in ______ or ______ ways.

---

one, more

7. The plant kingdom has been divided into eight groups under one classification table, called phyla (fi' la). The singular for phyla is phylum. Each of the plants in each phylum differs in some way from plants in the other phyla. The plants grouped within one of the four phyla are all alike in __________ or __________ ways.

---

phyla

8. The plant kingdom is divided into a few groups called ______________________________.

---

one
more

9. The phyla are divided into smaller groups called classes. A member of any class must be alike in ______ or __________ ways.

---

phyla classes	10. The plant kingdom is first divided into_____________, and phyla are divided into smaller groups called _____________.
one more	11. Classes are then arranged into <u>orders</u>. For example, the class of insects, <u>Insecta</u> has twenty-six orders. There is one order for butterflies, one for beetles, one for flies, etc. Members of an order must be alike in ________ or _____________ ways.
phyla classes orders	12. The plant kingdom is first divided into _____________, and phyla are arranged in smaller groups called __________, and classes are arranged in even smaller groups called _____________.
one, more	13. Within the insect order for flies there are many kinds of flies. There are fruit flies, house flies, horse flies, blow flies, etc. These different kinds of flies are called <u>families</u>. Orders, then, are further divided into families if the members are alike in __________ or __________ ways.
phyla classes orders families	14. The plant kingdom is first divided into _____________, and phyla are arranged in smaller groups called __________, and classes are arranged in even smaller groups called _____________. Orders consist of smaller groups called _____________.
one, more	15. Families are further divided into <u>genera</u>. (Genus is singular.) Plants which are members of a genus are alike in __________ or ____________ ways.
phyla classes orders families genera	16. The plant kingdom is first divided into ____________, and phyla are arranged in groups called _____________, and classes are arranged in smaller groups called ____________. Orders consist of smaller groups called _____________, and families are divided into _____________.
400,000	17. There is one more division of plant classification; genera are divided into <u>species</u>. However, a species is NOT a diverse group of plants, but rather one kind of plant. By one kind of plant is meant that the members can produce offspring among each other. There are approximately 400,000 kinds of known plants so there are _____________ (#) species.
offspring	18. A plant species can be compared to human beings. All human beings belong to one species. This means that all races of mankind are one kind of species and; therefore, the members can produce _____________ among each other.

Plant Kingdom Species (right side)	19. Fill in the missing blank on the right. Which of these groups contains the most members?__________	Plant Kingdom Phyla ______ Class ______ Order ______ Family ______ Genus ______ __________
Genus Species	20. Fill in the missing blanks on the right.	Plant Kingdom Phyla ______ Class ______ Order ______ Family ______ __________ __________
Phyla Family	21. Fill in the missing blanks on the right.	Plant Kingdom __________ Class ______ Order ______ __________ Genus ______ Species ______
Phyla Order	22. Fill in the missing blanks on the right.	Plant Kingdom __________ Class ______ __________ Family ______ Genus ______ Species ______
Class Order Family	23. Fill in the missing blanks on the right.	Plant Kingdom Phyla ______ __________ __________ __________ Genus ______ Species ______
Class Order Family Genus	24. Fill in the missing blanks on the right.	Plant Kingdom Phyla ______ __________ __________ __________ __________ Species ______

Class Order Family Genus Species	25. Fill in the missing blanks on the right. Plant Kingdom Phyla ______ ______ ______ ______ ______ ______
Phyla Class Order Family Genus Species	26. Fill in the missing blanks on the right. Plant Kingdom ______ ______ ______ ______ ______ ______
genus	27. Now let's see if you can work backwards. All the species (kinds) of pine are grouped in the genus, <u>Pinus</u>, and all the species of spruce in the genus, <u>Picea</u>. Therefore, similar species must be grouped into a particular ________.
family	28. Closely related genera are grouped into one ________.
order	29. Related families, such as all families of insects are classed under one ________.
class	30. Similar orders are grouped under one ________.
phylum	31. Classes are arranged under one ________.
kingdom	32. All the phyla make up the plant ________.
<u>strobus</u>	33. The scientific name of a species has two parts. The two parts are the species name and the genus name. If a species name is <u>strobus</u>, and the genus name, <u>Pinus</u>, the scientific name is <u>Pinus</u> ________.
plant kingdom	34. Species is the smallest group in the system of classification. That is, it contains only one kind of plant. The largest group containing <u>all</u> kinds of plants is the ________ ________.
species	35. Scientific names usually are in Latin form and the same scientific name is used throughout the world for a certain species. A scientific name consists of a genus name and a ________ name.

36. Common names of plants vary from country to country. In England "corn" means wheat, in Scotland "corn" means oats, and in the U.S. "corn" means Indian maize. By using the scientific name, everyone will be talking about the same plant in any country or language. Scientific names are usually in __________ form and the same name is used throughout the whole __________.

Latin
world

37. In our laboratory experience today we will be studying two closely related species of elm trees—the American elm, (Ulmus americana), and the Chinese elm, (Ulmus parnifoli). Both elms belong to the __________ genus.

Ulmus

38. Referring to the figure at the right, to what class does Ulmus americana belong?
____
____

Plant Kingdom
- Phylum Tracheophyta
  - Class Angiospermae
    - Order Urticales
      - Family Ulmaceae
        - Genus Ulmus
          - Species americana

Class
Angiospermae

39. Ulmus parnifoli is classified exactly like Ulmus americana except for the species. To what species does Ulmus parnifoli belong? __________

parnifoli

40. To what class does Ulmus parnifoli belong? __________

Angiospermae

41. Do both species belong to the same family? __________

Yes

42. To what order does the American elm belong? __________

Urticales

43. The Chinese elm belongs to what order? __________

Urticales

44. Ulmus americana is the scientific name for the American elm. Which name is its species name? __________

americana

45. Does the Chinese elm belong to the same genus as the American elm? __________

Yes, Ulmus

46. The elms comprise a group of 18 to 20 species widely distributed through the forests of North America, Europe and Asia. All 18 to 20 species would belong to what genus? __________ What family? __________

Ulmus, Ulmaceae

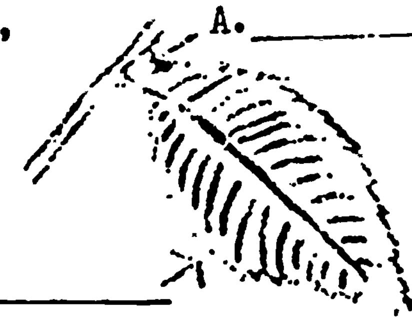
47. INFORMATION ITEM - NO RESPONSE REQUIRED

The elms grow rapidly and gracefully and are used often as ornamentals (to beautify or decorate), for lumber, and as shade trees. The American elm, however, is threatened by the Dutch elm disease and may become extinct (die out).

A petiole

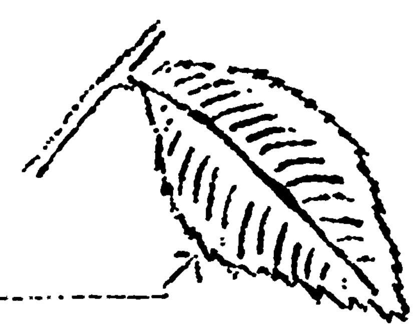
B. blade

48. The elms have simple leaves. A simple leaf consists of a <u>blade</u>, and a <u>petiole</u>. (pet' ee ol) The petiole is the stalk which supports the leaf and attaches it to the stem. Identify A and B in the figure at the right.



A. margin

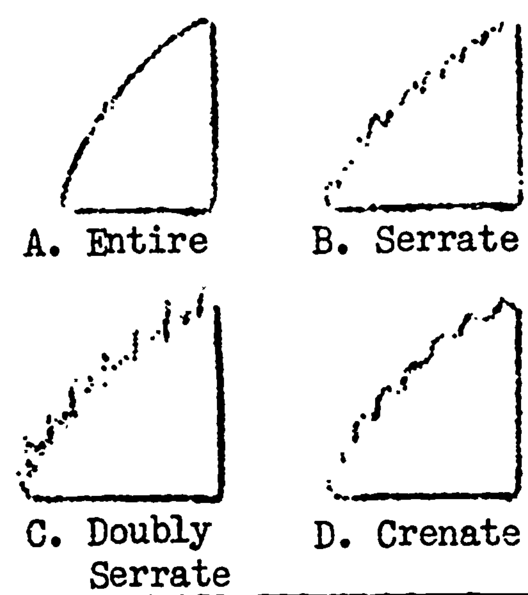
49. Leaf blades have <u>margins</u> which differ, among different trees. The margin is the exterior outline of the blade. Identify A in the figure at the right.



---

double

50. Some of the more common marginal patterns are shown in the figures at the right. The margins of B and C have notches which are typical of the elms we shall study. Notice that B has single notches while C has ______________ notches.



---

single

51. <u>Ulmus parnifoli</u>, the Chinese elm, has a <u>serrate</u> margin. A serrate margin has ______________________ notches.

---

serrate

52. By single notches is meant the notches are usually spaced evenly and are of the same size. The pattern of a single notched leaf margin is called ______________.

---

double

53. <u>Ulmus americana</u>, the American elm has a DOUBLE SERRATE margin. A double serrate margin has __________ notches.

---

doubly serrate

54. By double notches is meant the larger notches have a smaller notch inbetween them. The pattern of a double notched leaf margin is called __________ __________.

---

55. PROCEDURAL ITEM - NO WRITTEN RESPONSE REQUIRED

Now we are ready for the laboratory experiment. You will notice the materials and equipment are placed in the work area for you. Check over the following list and make sure you have these materials and equipment with which to work. The items numbered in the list correspond with the numbers on the materials and equipment which you see. Take these items to an area designated for you to work. Check the time; if you do not have approximately fifteen minutes to get started on the experiment, then spend the remaining portion of the period reviewing and studying the frames you have just covered. Allow five minutes to put the materials back in place in order to be ready for your next class.

1. Envelope of pressed leaves from the American elm
2. Envelope of pressed leaves from the Chinese elm
3. Empty envelope (to use in the event the bell rings and you have measured only a portion of an envelope of leaves. Place measured leaves in this empty envelope. Put the unmeasured leaves back in their original envelope. Store both on the paper with your name on it until the next science period.)
4. Millimeter rule
5. One sheet graph paper
6. Red and blue pencil
7. One Frequency Tally and Table chart sheet.

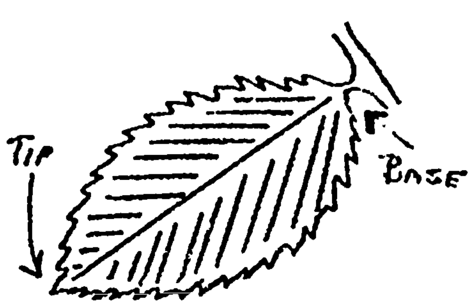
---

56. PROCEDURAL ITEM - NO WRITTEN RESPONSE REQUIRED

Choose either item 1 or 2 to take to your working area. Do <u>not</u> take an envelope of each species at the same time. As you work, you will need <u>more than one</u> envelope of each species They are numbered; record the number of the one you choose to work with. When you are finished, replace it at the work area and choose a different numbered envelope of the <u>same</u> species until you are finished with that species. Always choose a different number so that you will not be measuring the same leaves over again.

---

57. a. Take the leaves out of the envelope. PLEASE BE VERY CAREFUL with the pressed leaves since they will break easily. Students in other sections must use these same leaves also.



b. Work only with <u>one</u> species at a time. DO NOT mix the two species. Using your millimeter rule, measure the greatest length of one leaf, NOT including the petiole. Measure only the blade from the <u>tip</u> to the <u>base</u> of the leaf. (See the figure at the left.) As you measure each leaf, put it back in the envelope.

---

58. PROCEDURAL ITEM

a. Use the "Frequency Tally and Frequency Table Charts" sheet to record the various lengths of each species of elm tree. KEEP SEPARATE RECORDS OF EACH SPECIES. As you obtain a different length of leaf from a former one, label a row with that length, just as you did with the lima beans. Be sure you put down a tally mark for each leaf. You will have a much larger range of leaf lengths than bean lengths. You could have 50 to 100 different lengths. Use the whole length of the page for your frequency tally instead of just one frequency tally chart since you may have 50-100 different lengths. Go into the second column if you need to. (Refer to the figure at the left for setting up your frequency tally.)

b. Empty an envelope of leaves carefully. Pick out what look to be the smallest and the largest leaves. Measure their lengths. This will give you some indication of the range of your frequency tally. Usually the Chinese elm leaves will range from approximately 10mm to 75mm. The American elm leaves generally range from 60mm to 180mm. Keep your tallies in numerical sequence so you can tell at a glance if you're approaching a normal curve.

c. You will need to measure at least 100 leaves from each species before you approximate a normal curve. After you have measured 100 leaves from one species, convert your frequency tally into a frequency table. Do you have more leaves for the middle lengths, and a gradually decreasing amount on either side of the middle lengths? If so, then you need not measure anymore of that species. If you do not approach a normal curve, continue measuring until you do. Then set up a new frequency table.

d. Plot your distribution on one half sheet of graph paper. Use a red pencil to plot the date of the American elm, and a blue pencil to plot the data of the Chinese elm.

e. Along the y-axis you should start with one in case you have one leaf in any group length. Your largest number along the y-axis should be as large or larger than the greatest number of leaves in one size class.

f. Along the x-axis, start with the shortest leaf length in millimeters and include your longest length.

g. Space your figures along the x- and y-axis as you like, but try to have the y-axis about three-fourths as long as the x-axis. This makes a better picture of your graph.

h. Plot the data and connect your dots by lines.

i. Label the American elm graph, "1", and the Chinese elm graph, "2".

	Frequency
10mm	
11mm	
12mm	
13mm	
14mm	
15mm	
16mm	
17mm	
18mm	
19mm	
20mm	
21mm	
22mm	

	Frequency
23mm	
24mm	
25mm	
26mm	
27mm	
28mm	
29mm	
30mm	
31mm	
32mm	
33mm	
34mm	
35mm	

	Frequency
36mm	
37mm	
38mm	
39mm	
40mm	
41mm	
42mm	
43mm	
44mm	
45mm	
46mm	
47mm	
48mm	
49mm	

	Frequency
50mm	
51mm	
52mm	
53mm	
54mm	
55mm	
56mm	
57mm	
58mm	

59. PROCEDURAL ITEM – NO WRITTEN RESPONSE REQUIRED

a. Now choose an envelope of the species of elm you have not worked with.

b. Proceed with these leaves as you did with the other species. Measure the length of each leaf.

c. Record your data on a second sheet of frequency tallies, just as you did before.

d. When all the measurements and observations are finished, and you have measured a representative sample which approximates a normal curve, go back to your sheet of graph paper. (Again, you might ask your teacher to check your frequency table to see if your figures approximate a normal distribution.)

e. Record the data on the other half of your sheet of graph paper.

f. Use a red pencil for American elm data and a blue pencil for the Chinese elm data.

g. Be sure your name is on the sheet of graph paper. Keep it for further study.

h. A graph should always have a title. The name of the correct species will be sufficient for the title of your graphs. Title your graphs now. If you can think of another description you would like to use for your title, do so.

---

60. Compare the two graphs. Is there any overlap, that is, are some of the leaves in both species the same length?

Answer depends upon results; there should be

____

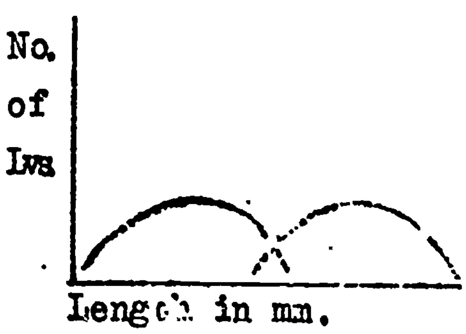
61. How much overlap do you have in millimeters?__________

Answer depends upon results

62. PROCEDURAL ITEM

Now take another piece of graph paper. Put the same figures along the x-axis and along the y-axis that you did for graph "1", and graph "2". Include the largest range in both graphs. Use the red pencil to plot the American elm data, and a blue pencil to plot the Chinese elm data. Connect the dots by lines. Does this give a better picture of overlapping lengths of leaves?______________
(Check the graph at the left. Your graph should resemble this one.)

It should give a better picture.



Answer will depend upon results

63. If your results yielded an overlap of 15mm. that is very good. What conclusions would you draw from the comparison of lengths of the two species on your graph as to the nearness of relationship of the two species?________

Answer will depend upon results

64. From the sample of leaves drawn from the total population of leaves from the American elm tree, do the related events seem to form a pattern of a normal, bell-shaped curve?________

Answer will depend upon results

65. Does your sample of Chinese elm leaf lengths show a normal distribution?________

Answer depends upon results

66. Have the data "piled up" on graph "1"?________

Answer depends upon results

67. Where is the mode located on graph "1"?________

Answer depends upon results

68. Have the data "piled up" on graph "2"?________

Answer depends upon results

69. Where is the mode located on graph "2"?________

70. PROCEDURAL ITEM - NO WRITTEN RESPONSE REQUIRED

a. Check with your teacher to see if there is time for you to proceed with this section. If not, please go to frame 86.

b. Now measure the <u>greatest width</u> of each leaf in an envelope Do this for each species. You will have to estimate, using your judgment as to where the leaf is the widest. Work with only ONE SPECIES at a time.

c. Set up a frequency tally and a frequency table for the information on the widths of your leaves.

d. When you have measured a representative sample of leaves in each species and recorded the tally marks, set up frequency tables.

e. Plot these data on another sheet of graph paper.

f. Label the American elm data "3", and the Chinese elm data "4".

g. Remember to use the proper colored pencils.

h. Title your graph and file it for further study. Do you have some overlapping again? ________

There should be if your sample is large.

There should be with an adequate sample

71. Compare graphs "3" and "4". Is there any overlap of leaf widths in the two species?__________________

Answer depends upon results

72. How much overlap do you have in millimeters?_________

Answer depends upon results

73. What conclusions whould you draw from the comparisons of widths as to the nearness of relationship?____________

Answer depends upon results

74. Where is the mode located on graph "3"?______________

Answer depends upon results

75. Where is the mode located on graph "4"?______________

76. Check with your teacher to see if there is time for you to complete this section. If not, please skip to frame 86.

a. Place a leaf top-surface downward and count the number of notches on the right side of the leaf. (In the American elm consider only the <u>large</u> notches.) In determining "right" and "left", consider right and left to correspond to your own right and left hands. Work with one envelope of leaves at a time for one species.

b. Secure a frequency tally chart and a frequency table chart from the main supply.

c. When you have counted the right side notches of all your sample of leaves and recorded the data, plot the data on a third sheet of graph paper as you did the other data.

d. Label the American elm graph "5" and the Chinese elm graph "6". Keep the graph for further study.

There should be if the sample is large.

77. Compare graphs "5" and "6". Is there any overlapping evident in the number of notches on the right side?_______

Answer depends upon results

78. What conclusions would you draw from the comparison of right side notches as to the nearness of relationship?

Answer depends upon results

79. Where is the mode located on graph "5"?______________

Answer depends upon results

80. Where is the mode located on graph "6"?______________

81. PROCEDURAL ITEM

a. Check with your teacher to see if there is time for you to complete this section. If not, please go to frame 86.

b. Place a leaf top-surface downward and count the notches on the left side of the leaf. (Remember the American elm large notches are only considered.)

c. Secure a frequency tally chart and a frequency table chart from the main supply.

d. When you have counted the left side notches of all your sample of leaves and recorded the data, plot the data on a fourth sheet of graph paper as you did the other data.

e. Label the American elm graph "7" and the Chinese elm graph "8". Keep the graph for further study.

Answer depends upon results

82. Compare graphs "7" and "8". Is there evidence of overlap in the number of notches on the left side?________

Answer depends upon results

83. What conclusions would you draw from the comparison of the number of left side notches as to the nearness of relationship?________

Answer depends upon results

84. Where is the mode located on graph "7"?________

Answer depends upon results

85. Where is the mode located on graph "8"?________

---

86. This frame is a homework assignment for you tonight. Please write down ten questions which you can raise concerning the idea of normal curves and sampling. They should not be questions requiring only a definition but such as the following:

Does everything have warping factors?
Does your hypothesis always become a law?
Why doesn't nature form true normal curves?

Turn this assignment in to your teacher tomorrow morning. If your science period is in the afternoon, then, of course, you turn your assignment in at your regular class period.

---

87. FURTHER INVESTIGATIONS

Set up similar comparative studies for other species. What about species of dogwoods? What about hawthorns? What about oaks? Note that this kind of study is valuable

only for closely related species. More distantly related species are readily distinguished by characteristics which do not overlap.

---

88. Try to write a general description of each species from the date that you have, in such a way that a person seeing them in nature could readily distinguish them. These are the kinds of data taxonomists use in describing species and distinguishing them from one another.

---

89. If you have time remaining in the period begin on the next programmed lesson. File this lesson in a safe place so that you may review it later.

THINKING ABOUT MEASUREMENT AS AN EXPRESSION OF RELATIONSHIP

Section ________ Name ____________________

building — 1. The idea of measurement is a matter of comparing the thing to be measured with something else. We say a building is sixty feet long. We have compared a foot rule with a ______________________________.

sixty — 2. To measure means to determine the extent or limit of something. We have found a building to be sixty feet long. The extent or limit of this building's length is ________ feet.

twenty — 3. An object's limit or extent can be expressed differently. It depends upon what you are comparing with the object. If we compared a yard with a sixty-foot building its extent or limit would be ______________ yards.

limit — 4. Neither a yard, nor a foot, nor any other unit of measure is anything that actually exists. They are merely standards that men have agreed to use to compare the extent or ______________ of something.

exists — 5. For example, in the English system the unit of length measurement is the yard. Scientists agreed that a yard would be the distance between two lines crossing two gold studs set in a bar of platinum kept in London. A unit of measurement is not an object that actually __________.

exists — 6. Time exists without beginning or end. We conveniently break up time spans into hours, days, or minutes. An hour is a unit of measurement but not an object that actually ______________________________.

yard — 7. A representation of a unit of measurement can be made, however. The foot or twelve-inch ruler is used to represent a foot. A yardstick is used to represent a ________.

representation — 8. A clock is a mechanical device used to measure time in hours, minutes, and seconds. A clock is a ______________ of a unit of measurement of time.

standard — 9. A concrete or actual representation of a unit is called a standard. A yardstick would be called a ______________.

standard

10. A clock, used to represent units of time measurement, would be a ________________.

---

unit

11. Some of the earliest standards of length were the width of a hand, the length of a king's foot, or a cubit (the length from elbow to tip of middle finger). The height of a horse would be measured by so many widths of a man's hand. The hand, foot, or cubit were used to represent a ________ of measurement.

---

unit

12. An early standard of weight was the weight of a stone. The stone was used to represent a ________ of measurement.

---

unit

13. The length of time necessary to burn a rope or a candle was often used by primitive people to measure time. The burning rope or candle was used to represent a ________ of measurement.

---

exactly

14. The obvious objection to such standards would be their tendency to vary. One man's hand or foot might be smaller than another's. Definite standards such as the yard, pound, or gallon make measurement more exacting. A clock measures time more ____________ than a burning rope or candle.

---

cycle

15. Many common time measurements are based on the length of <u>cycles</u> of one sort or another. A cycle is a complete set of events recurring in the same pattern. The phases of the moon recur every 28 days. This set of events would be called a ________________.

28

16. The American Indians and other primitive peoples measured time in <u>Lunar</u> (means "moon") cycles. This cycle recurred every (#) __________ days.

---

cycle

17. The time it takes for the earth to make a complete turn on its axis is a day. The set of events from one day to the next is called a ________________.

---

cycle

18. The earth makes one complete circuit of the sun every year. This set of annual events is called a __________.

---

cycle

19. We sometimes say "This is 'springTIME' or 'summerTIME'. We measure time by seasons also. The set of seasonal events is called a ________________.

---

unit

20. Temperature is measured by the expansion or contraction of mercury within a thermometer divided into units called degrees. A temperature is not an object that exists but it is represented by a _______________ of measurement called a degree.

---

unit

21. Sound is not an object that exists but is measured by a representative _____________ of measurement, the number of vibrations within a given time.

---

exist
standard

22. Whatever the type of measurement, we measure something by comparing it with something else. A unit of measurement does NOT actually _____________, but it has an actual, concrete representation called a _________________ .

---

standards

23. Increased need and wider use brought the necessity of definite standards of measurement. The Metric System has gradually been replacing the old units. The Metric units of measurement are not objects which exist, but have actual, concrete representations called _________________________.

---

millimeter

24. Recall that scientists use the Metric System since all the units can be converted into other units by multiples of ten. In previous laboratory experiences you have been using a ______________________ rule often, which is a standard of the Metric System.

INFORMATION ITEM -- NO RESPONSE REQUIRED
Frames 25-35 are a review of the units on measurement in the Metric System.

100

25. The fundamental length unit in the Metric System is the standard meter (m). It is slightly longer than the yard in the English System—39.37 inches to be exact. The meter can then be divided into centimeters. "Centi" means "one hundred<u>th</u>" so there would be ___________ centimeters (cm) in one meter.

1000

26. "Milli" means "one thousand<u>th</u>", so there would be _______________ millimeters (mm) in a meter.

1000

27. In the English System 1760 yards equal a <u>mile</u>. In the Metric System a certain number of meters equal a <u>kilometer</u>. If "kilo" means a <u>thousand</u>, there would be _______________ meters in a kilometer (km).

1000

28. The basic Metric standard of mass is the kilogram (kg). It equals 2.2 pounds. From what you have learned defining "kilo", a kilogram contains _____________ grams (g). A

gram is related to a kilogram somewhat as an ounce is related to a pound.

---

km^2

29. For area measurements in the Metric System we have square centimeters, square kilometers, etc. To write abbreviations for the area units we use exponents as a shorthand notation. Square centimeters is written cm^2; squared kilometers is written ________.

---

cm^3

30. Bulk or volume requires a cubical unit for measurement. Cubic feet is written, ft^3. Cubic centimeters is written ________.

---

liter

31. There is a special name given to a Metric unit of volume equal to 1000 cm^3. It is called a liter (pronounced "leeter") and is just larger than a liquid quart. Going back to what we learned as a definition for "milli", meaning thousandth, a milliliter (ml) is 0.001 liter (l). Or 1000 milliliters equals one ________.

---

one thousand

32. A cubic centimeter is, for all practical purposes, the same volume as a milliliter. If one thousand milliliters equal one liter, ____ ________ cm^3 equal one liter. This is an important relationship to remember.

---

one

33. To repeat, one cubic centimeter equals ________ milliliter.

---

ten
meter
yard
0.01
0.001
1000

34. Now let's review the discussion on the Metric System. All the units in the Metric System can be converted into other units by multiples of (1) ______. The length unit is the (2) ________. It is slightly longer than the (3) ________, in the English System. A centimeter is (4) ________ meter. A millimeter is (5) ________ meter. A kilometer equals (6) ________ meters.

---

kilogram
1000
length
cm^2 or km^2
cm^3

liter; one
0.001

35. The Metric unit of mass is the (1) ________, which represents (2) ________ grams. The metric units for area and volume are based on the (3) ______ units. Area is expressed in (4) ________; volume is expressed as (5) ________. The special name given to a Metric unit of volume equal to 1000 cm^3 is a (6) ________. One cm^3 is equal to (7) ______ milliliter. A milliliter equals (8) ________ liter.

---

36. In one experiment you worked with microscopic yeasts. You will be working with another microscopic organism

animal

called a paramecium. A paramecium is a one-celled animal and, therefore, belongs to the ______________ kingdom.

Infusoria

37. One-celled animals belong to the phylum, Protozoa. Those in class Infusoria have cilia. Paramecia have cilia so they belong to class ______________.

---

cilia

38. Cilia are hairlike outgrowths from a cell which serve to propel the microorganism through the water. Paramecia are propelled through water by ______________.

Paramecium caudatum

39. Paramecium is a genus name for these one-celled animals. The species name of the one we will be working with is caudatum. Recall that the scientific name consists of a genus and a species name. The scientific name for this protozoan is ______________ ______________.

---

drive food into the mouth

40. The cilia also drive food into the large mouth in a fold at the side of the paramecium. It feeds chiefly on bacteria. Cilia, then, are used to propel the animal through water and (own words) ______________.

---

bacteria

41. Paramecia feed chiefly on ______________.

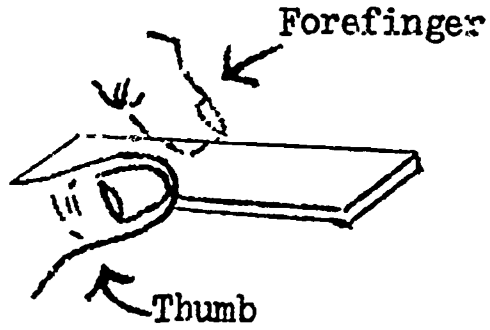
---

42. INFORMATION ITEM - NO WRITTEN RESPONSE REQUIRED

a. It will be necessary for you to use the microscope in this exercise. Study frames 43-127 carefully. Even if you already know how to use the microscope, you will need to read these frames inasmuch as the projection drawing technique is also taught within these frames.

b. Look for a sign entitled, "Thinking About Measurement as an Expression of Relationship". There you will find supplies and equipment to use in this experiment. Items numbered 2-6 should be collected now and brought to your seat. As you read, you will be told when to obtain item 1. The following list designates the six items you will be needing during the immediate section of your lesson:

1. Microscope
2. Microscope slide
3. Small section of graph paper with "a" typed on it
4. Lens paper
5. Piece of typing paper
6. Millimeter rule



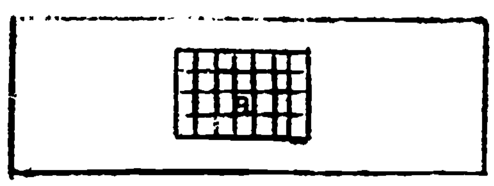
43. Take a clean slide from the container, being careful not to touch the large flat surface of the glass with your fingers as any material deposited will be magnified hundreds of times. The proper way to handle the slide is to grasp it along its sides with the forefinger and thumb as shown in the diagram to the right.

---

44. Lay the slide flat on the laboratory table directly in front of you.

---

45. Take a section of graph paper and find the small letter "a" within a block.



Top View

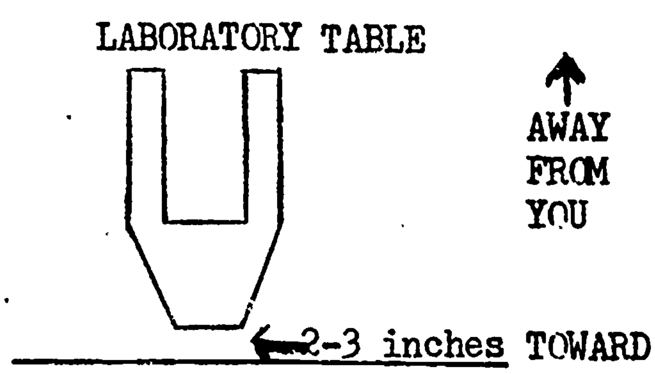
46. Place the letter print side up on the slide. If you think it needs to be more secure, take a small amount of scotch tape and fasten the section of graph paper to your slide.

---

47. As you proceed, keep the illustrations of the two types of microscopes before you for a handy reference.

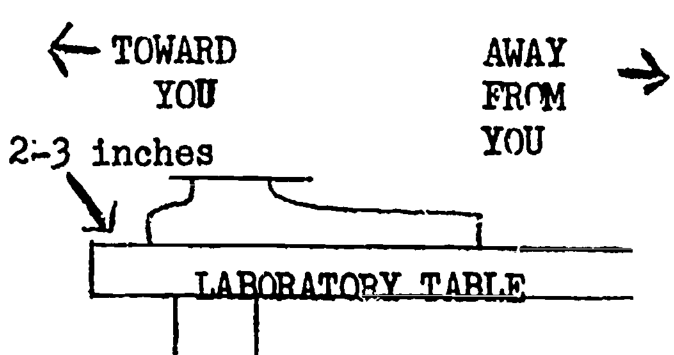
---

48. If a microscope is available at this time bring it to your desk, or go to work with it at the area designated by your teacher. If one is not available, go to frame 128 and work to frame 171. Then you can easily come back to this frame later.



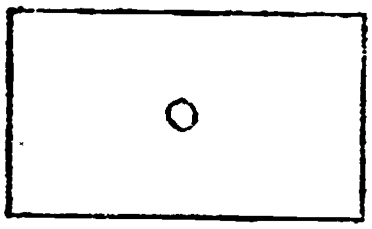
TOP VIEW of BASE ONLY

49. Take the cover off the microscope if one is present. Position the microscope by moving the U-shaped BASE so that it is about 2 to 3 inches from the edge of the laboratory table; the closed end of the U should be toward you.



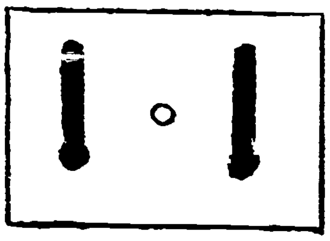
SIDE VIEW of BASE ONLY

50. The function of the base is one of support for the microscope.

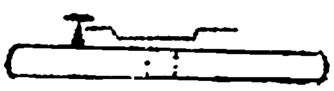


TOP VIEW
of STAGE ONLY

51. Locate the part called the STAGE. The function of the stage is to provide an area for the slide to be positioned for viewing.

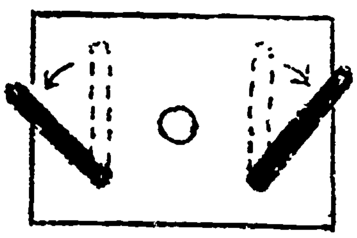


TOP VIEW



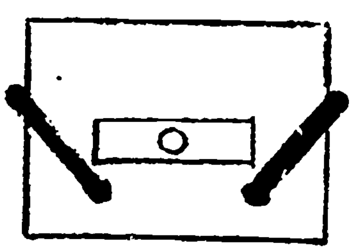
SIDE VIEW

52. Notice that on the stage are two CLAMPS. These will hold the slide in place.



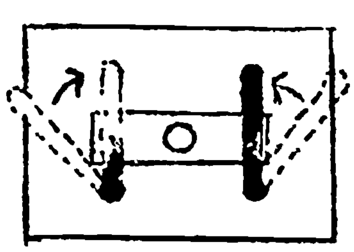
TOP VIEW

53. Rotate the clamps to the outer edge of the stage by lifting the unattached end.



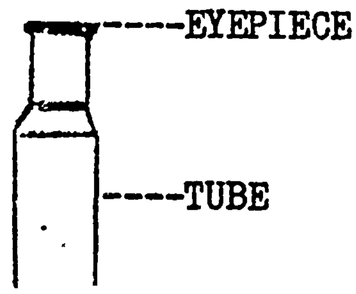
TOP VIEW

54. Pick up the slide by the edges so that you will not get it dirty and place it right side up on the stage so that the material on your slide is about in the center of the opening in the center of the stage.



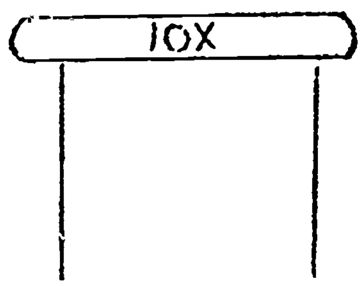
TOP VIEW

55. Replace the clamps on the slide in their original position.



SIDE VIEW

56. You will use two lenses for viewing any material. Locate the first, the EYEPIECE, at the top of the TUBE.

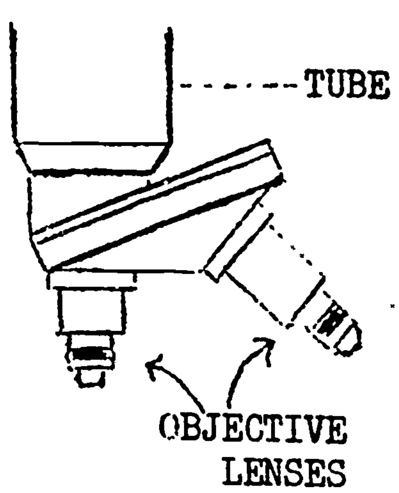


SIDE VIEW (ENLARGED)

57. Notice that written on the eyepiece is the MAGNIFICATION. Magnification in this case means how many times the lens, if used by itself, will enlarge what you are viewing.

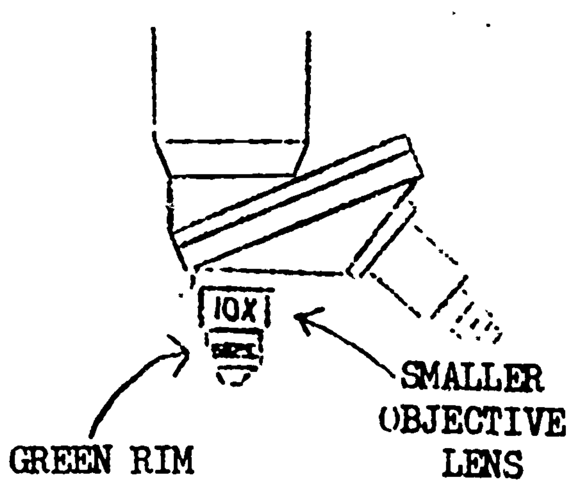
58. 10X means that the lens in the eyepiece would magnify or enlarge whatever is on your slide ten times if used by itself.

59. The eyepiece will later be the lens through which you will look to see the material on your slide, hence the name eyepiece.



SIDE VIEW

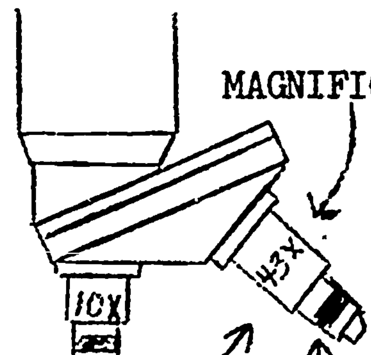
60. The second lens you will use is at the bottom of the tube. Notice that there are two lenses there. They are both called the OBJECTIVE LENSES.



SIDE VIEW

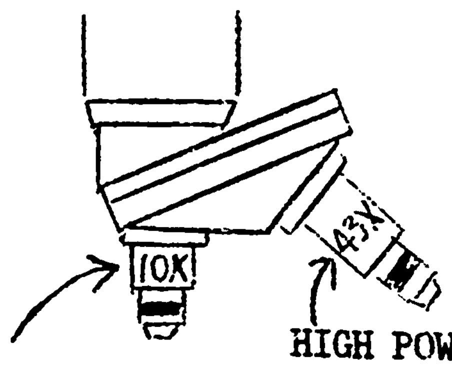
61. Notice that the smaller objective lens with the green rim around it also has a certain magnification.

62. We see that the smaller objective lens is marked 10X, and if used alone, would magnify the material on your slide ten times.



SIDE VIEW

63. Notice the larger objective lens with the yellow rim around it. This has a magnification of 43X. Again, this would mean that if used alone, the lens would enlarge the material on your slide forty-three times.



SIDE VIEW

64. Because of their differences in magnification, we call the smaller lens the LOW POWER OBJECTIVE LENS and the larger lens the HIGH POWER OBJECTIVE LENS.

---

65. Remember, we use only two lenses at any given time when using the microscope. One will always be the eyepiece, the other will be whatever we decide to use, either the low power objective lens or the high power objective lens.

MAGNIFICATION = EYEPIECE X OBJECTIVE IN USE

MAGNIFICATION = 10 X 10

MAGNIFICATION = 100

66. If we use the eyepiece (10X) and the low power objective lens (10X), we will see the object on our slide 100 times its original size. Thus, we can find the magnification by multiplying the power of the eyepiece (10X) by the power of the low power objective lens (10X).

---

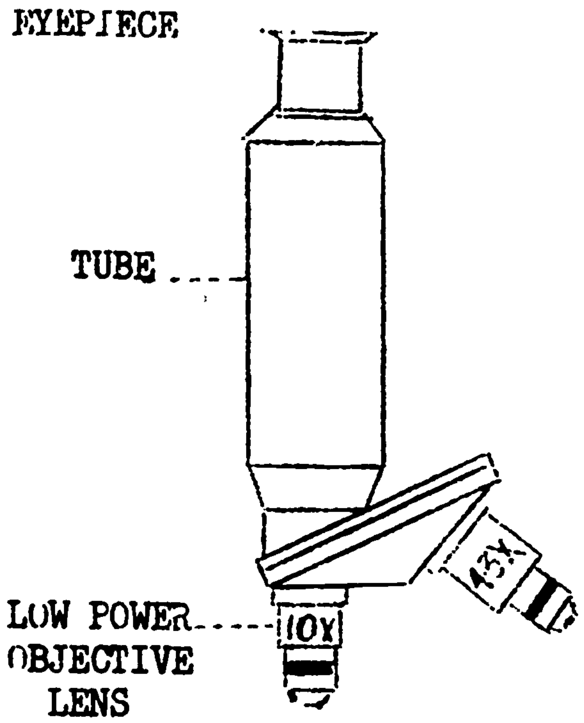
67. If we use the eyepiece (10X) and the high power objective lens (43X), we will see the material on our slide four hundred and thirty times its natural size. (430X)

MAGNIFICATION = EYEPIECE X OBJECTIVE IN USE

MAGNIFICATION = 10 X 43

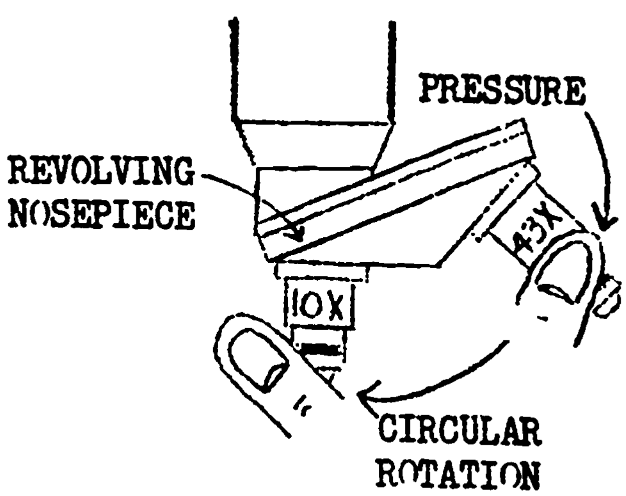
MAGNIFICATION = 430

68. Again, we found the magnification by multiplying the power of the eyepiece (10X) by the power of the high power objective lens (43X), the lens at the base of the tube <u>in use</u>.



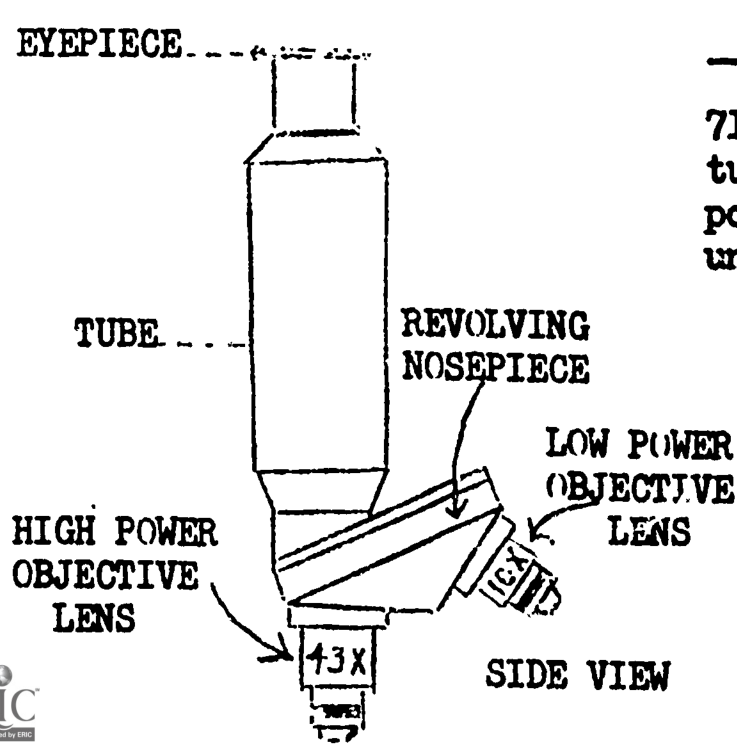
SIDE VIEW

69. Now let's see how we can use the different objective lenses. The way the microscope is set up now, the tube directly connects the eyepiece and the low power objective lens, so we are said to have the microscope set up for <u>LOW POWER</u>.



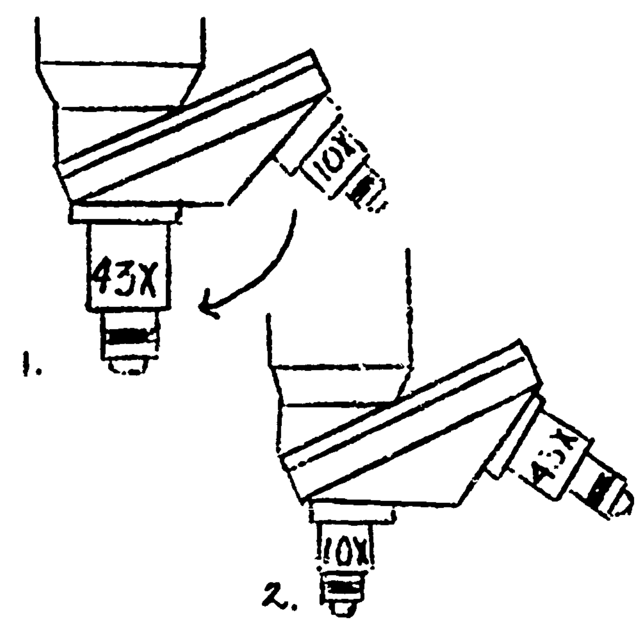
70. Locate the <u>REVOLVING NOSEPIECE</u> in which the objective lenses are set. You can view something on the higher magnification (430X) by putting your thumb on the low power objective lens and your forefinger around the high power objective lens and applying pressure on the lens in a clockwise motion. Rotate the lens until it <u>CLICKS</u> into place over the slide.

SIDE VIEW



SIDE VIEW

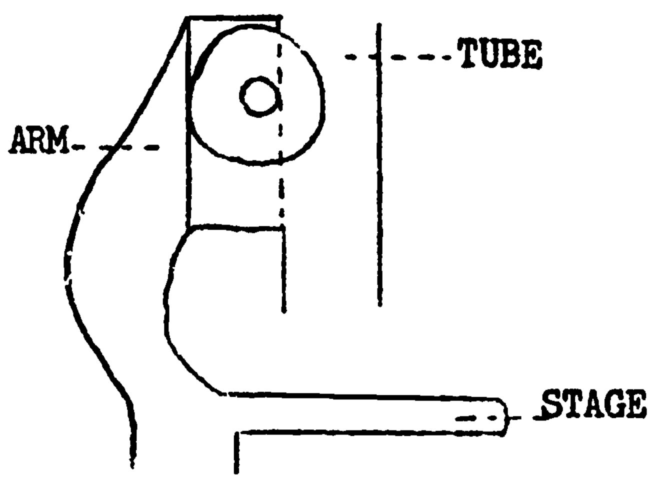
71. The way the microscope is set up now, the tube directly connects the eyepiece and the high power objective lens, so we view the material under HIGH POWER with this arrangement.



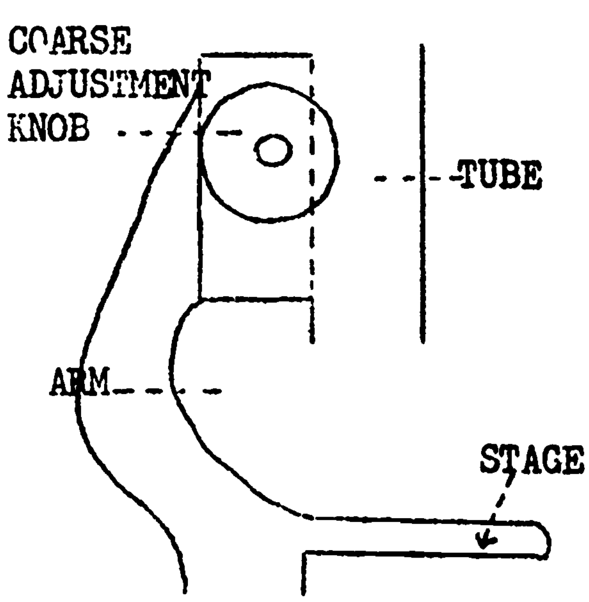
72. Return the low power objective lens to its original position in line with the tube by putting your thumb on the high power objective lens and your forefinger around the low power objective lens and applying pressure clockwise.

---

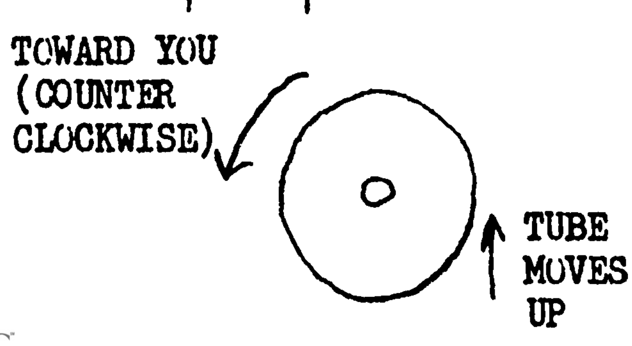
73. Now that you know where the different lenses are, take a piece of lens paper and carefully clean the glass parts of the lenses by wiping them off a few times.



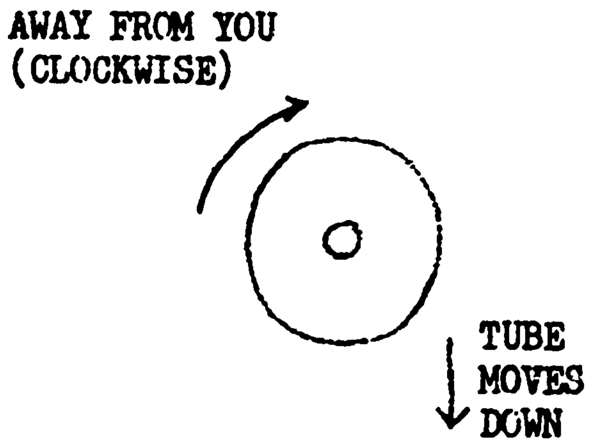
74. Next locate the <u>ARM</u>.



75. On the arm locate the large <u>COARSE ADJUSTMENT KNOB</u>. It is on both sides of the microscope so that it can be used with either hand. You will use it later to bring the material on the slide roughly into focus.



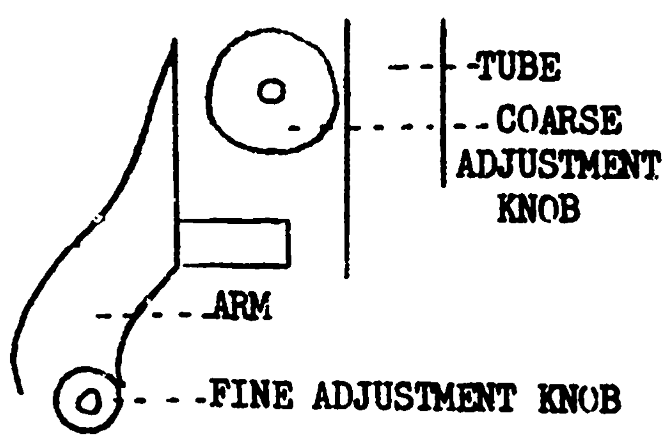
76. Notice that when you turn the coarse adjustment know TOWARD YOU, the tube will move UP toward you. There is no need to look through the eyepiece at this time to view the action of the adjustment.



77. Now turn it AWAY FROM YOU as far as you can, and you will notice that the tube moves DOWN, away from you, toward the slide.

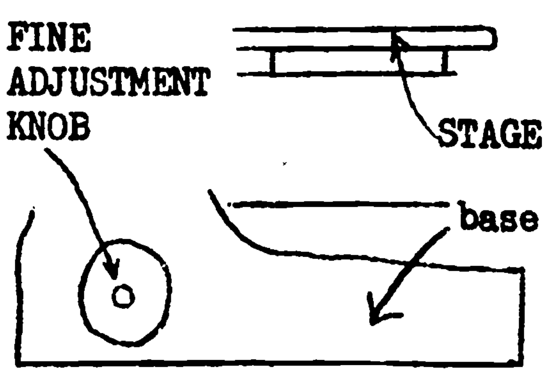
---

78. Next we want to take a look at the <u>FINE ADJUSTMENT</u>. If your microscope uses a mirror as a light source, READ ITEM 79; if your microscope has an electric light source, SKIP 79 and START AT 80. If you don't know which type microscope you will be using, study all the frames.

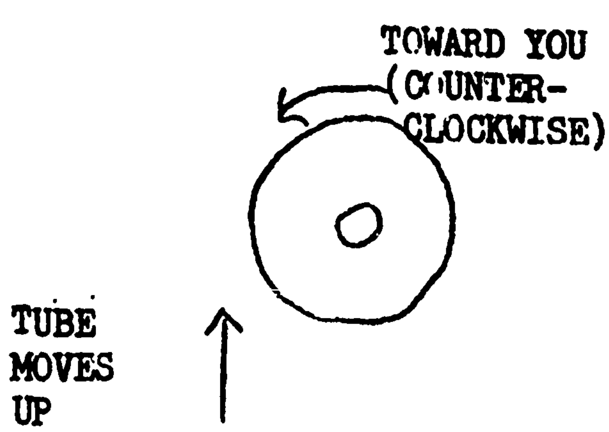


SIDE VIEW

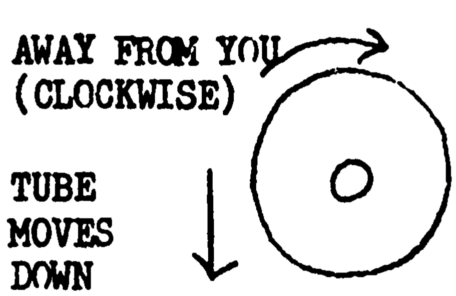
79. Locate the <u>FINE ADJUSTMENT KNOB</u> on the arm below the coarse adjustment. Go to item 81.



80. Locate the <u>FINE ADJUSTMENT KNOB</u> near the base.



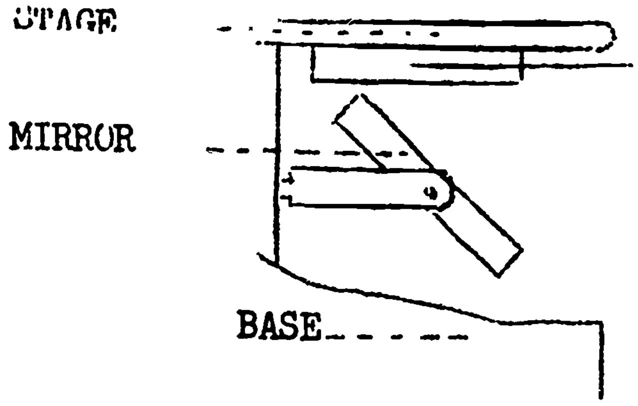
81. Like the coarse adjustment, notice that when you turn the fine adjustment knob TOWARD YOU, the tube move UP toward you and away from the slide. You will probably not be able to tell this unless you closely and carefully watch the objective lens.



82. Likewise when you turn the fine adjustment knob AWAY FROM YOU, the tube will move DOWN, away from you.

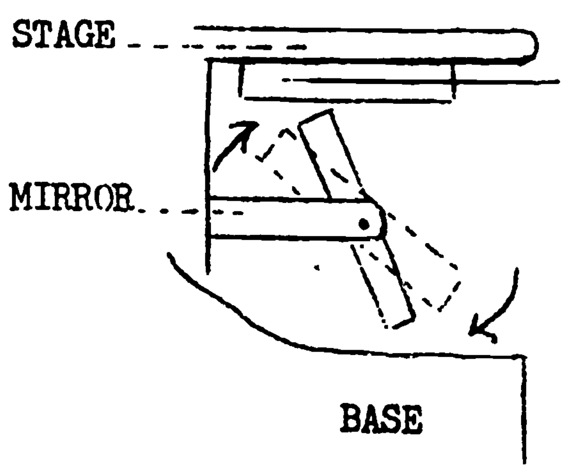
---

83. Next the adjustment of the light is necessary. If your microscope has a mirror as a light source, start at item 84; if it has an electric power source, skip to item 91. If you don't know which type you'll be using, read all frames.



SIDE VIEW

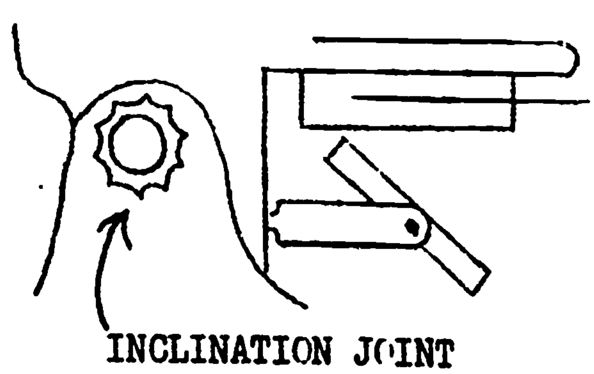
84. Locate the MIRROR.



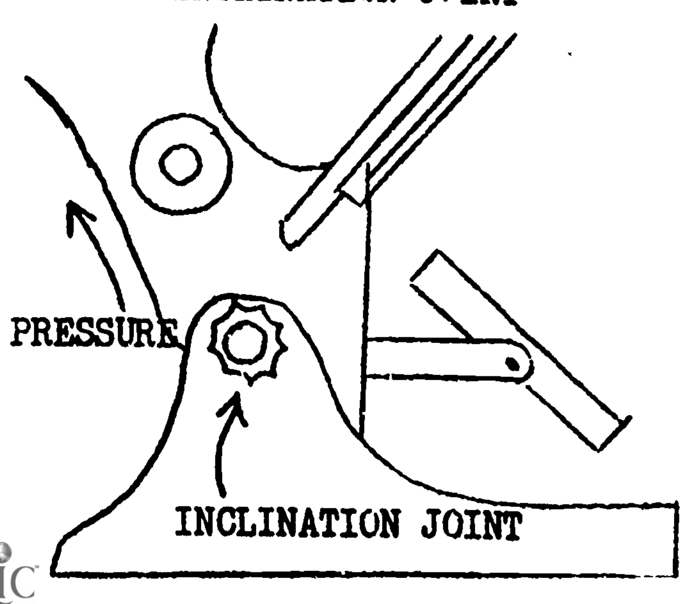
SIDE VIEW

85. Notice that you can move the mirror by grasping it at the edges and applying a little pressure.

86. Wipe off the face of the mirror with lens paper.



87. Before adjusting the mirror, locate the INCLINATION JOINT. The function of the inclination joint is to enable you to adjust (or incline) the position of the eyepiece to a comfortable angle for viewing.



88. This can be done by firmly holding the base with one hand and grasping the arm with the other. Tilt the microscope by applying pressure on the arm until the eyepiece is at a comfortable position for you to see through while seated.

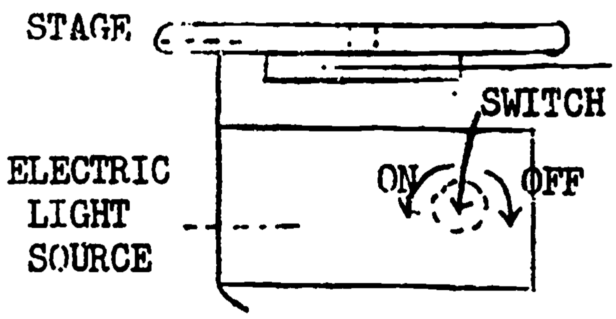
89. Check to see that the position is right by looking through the eyepiece. (You will find that with experience it is easier and causes less strain to leave both eyes open.) While looking through the eyepiece, adjust the mirror until you get the brightest light. Be sure that the mirror is not in the sun as the microscope will magnify it and cause damage to the eyes.

---

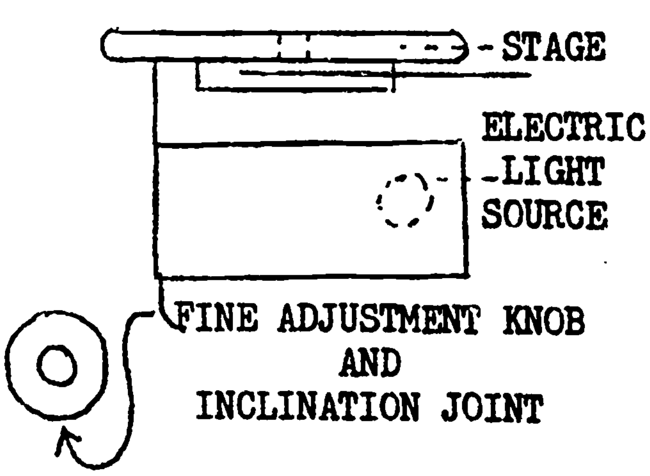
90. After you have adjusted the mirror, skip ahead to item 96.

---

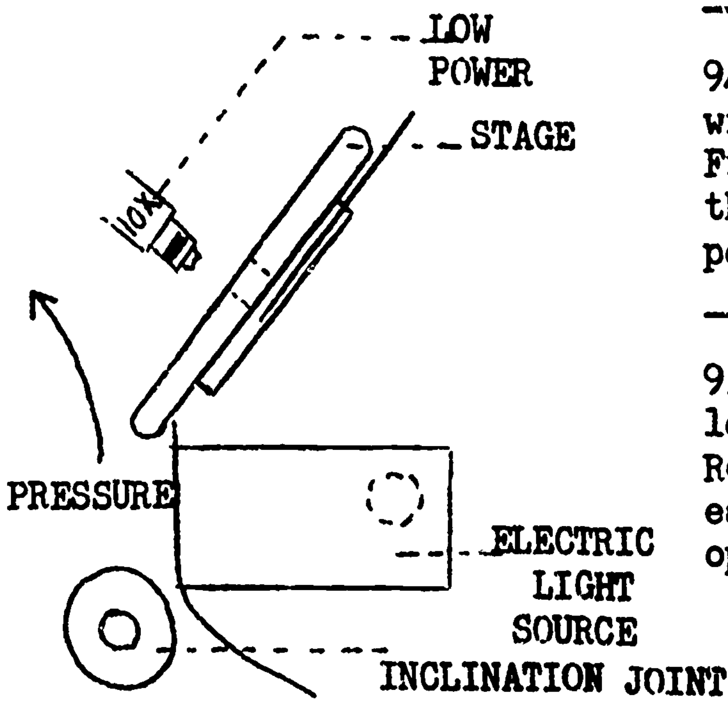
91. First put the plug in the electrical outlet.



92. Locate the switch at the left side of the electric light source. Turn it on by turning it toward you until it clicks.



93. Locate the INCLINATION JOINT. On your particular microscope, it is the same as the fine adjustment knob. The function of the inclination joint is to enable you to adjust (or incline) the position of the eyepiece to a comfortable angle for viewing.



94. This can be done by firmly holding the base with one hand and grasping the arm with the other. Firmly tilt the microscope by applying pressure to the arm until the eyepiece is at a comfortable position for you to see through while seated.

---

95. Check to see if the position is right by looking through the eyepiece with one eye. Remember that you will find with experience it is easier and causes less strain to leave both eyes open.

---

96. Before focusing check and see that you have the microscope on low power, the coarse adjustment knob is turned as far down, away from you, as possible, and that the material on the slide is about in the center of the opening in the stage.

---

97. With your eye to the eyepiece, SLOWLY turn the coarse adjustment knob TOWARD YOU (counter-clockwise) so that the tube moves up. Keep turning it until the material comes roughly into focus. (If the tube goes up more than one inch, you will not get the material in focus. You have either gone too fast and missed it or you might check the position of the material on the slide and see that it is in the center of the opening in the stage.)

---

98. After you get it roughly in focus, use the fine adjustment to sharpen the image. Then position the letter so that you can see all of it.

---

99. Note the position of the material under the microscope. The letter is reversed so that the letter "a" should appear upside down.

---

100. Note also that what looks like a continuous printed letter to the unaided eye, now appears to be rough ink blots on coarse paper fibers.

---

101. While looking through the microscope, slowly move the slide to the right with your finger. Note that the image moved in the opposite direction or to the left.

---

102. While looking through the microscope, slowly move the slide to the left until the image reaches the center of the field of vision again. Note that the image moved in the opposite direction or to the right.

---

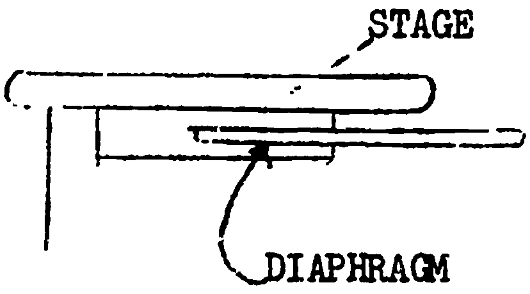
103. Move the slide slowly forward toward the upper edge of the stage. Note that the image moves in the opposite direction.

---

104. Move the slide back toward the center of the field of vision and again you will see that the image appears to move in the opposite direction.

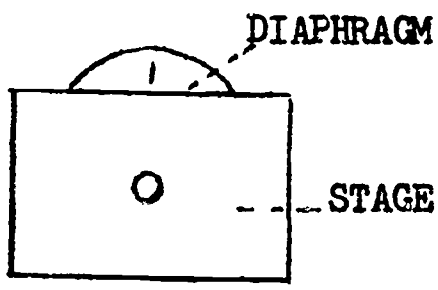
---

105. While looking through the microscope, you will have to try to remember that all directions are opposite your movements. This will come with experience.



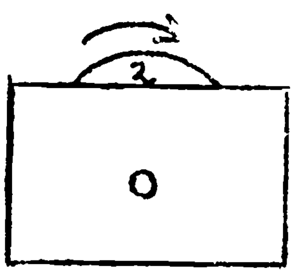
SIDE VIEW

106. The last part of the microscope is the <u>DIAPHRAGM</u> (di-ah-fram). It is designed to allow varying amounts of light through the stage. Sometimes we can see different structures better under different intensities of light.



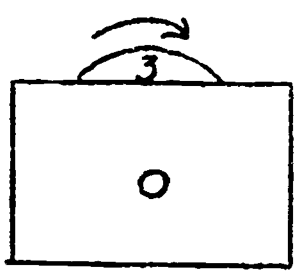
TOP VIEW

107. Note that at the edge of the stage is the diaphragm wheel and that the number "1" appears.



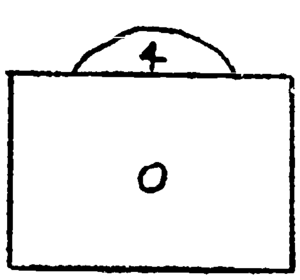
TOP VIEW

108. With your finger turn the diaphragm wheel to the <u>right</u> and the number "2" will appear. Look in the eyepiece and note any change in the intensity (brightness) of the light.



TOP VIEW

109. Repeat the process by turning the diaphragm wheel right to "3" and view the slide again.



TOP VIEW

110. A final turn will position the diaphragm at "4", giving us the brightest light. Now we are ready to shift to high power.

111. Once more check to see that the letter is in sharp focus in the center of the field of vision.

112. Carefully rotate the high power objective lens until you hear it click in place under the tube. If you did it carefully, the slide should

be automatically in focus under high power. If you see that the high power objective lens will hit the slide, turn the coarse adjustment knob toward you about an inch and try again.

---

113. Under high power, use only the fine adjustment to focus if needed. While looking at the letter, focus only by turning toward you. If you need to focus by turning away from you, look to the side to make sure that the lens is not going to crush the microscope slide.

---

114. When the letter is in focus, notice that you can only see a portion of the letter and that the light is dimmer. Remember that you are seeing the object 430 times its natural size, and the light that was on only a small part of the letter before, is filling up the entire field of vision.

---

115. Now turn back to LOW power. Focus the letter "a" again.

---

116. Put a sheet of typing paper just to the right of the microscope base if you are right-handed. Place it to the left if you are left-handed.

---

117. Observe the letter "a" within the block of graph paper with your left eye if you are right-handed, and with your right eye if you are left-handed.

---

118. Visualize with your other eye the same image on your sheet of typing paper that you see through the microscope. At first you will think this is impossible, but keep looking even though you think you'll never see anything. Wait patiently. Keep trying.

---

119. Once you see the image projection, it can then be traced with your pencil. Trace the block of graph paper in which you find the letter "a".

---

120. This is called "projection drawing". You have seen an image projected on a sheet of typing paper, and have drawn this image. Thus it is called "projection drawing".

---

121. After you have drawn the image of the block, measure one side in millimeters. All sides are the same so the measurement of one is sufficient.

---

122. What is the length of the image of the block in millimeters?

About 3.5 millimeters

123. Now measure the actual block of graph paper along one side. Its length in millimeters is ______________.

---

124. To calculate how much your image was enlarged or magnified you need only to divide your answer in frame 123 into the answer of frame 122. Dividing the length of the actual block of graph paper into its image gives you the degree of magnification. The degree of magnification is the number of times your image was enlarged at a distance from the ocular to your sheet of typing paper.

Answer depends upon results

125. What is the degree of magnification of your image? ______________

---

126. Find the number on the microscope which you have just used. What is the number? __________

---

127. Later you will need to use the microscope again and it would be best to use the same microscope, if possible. Put the microscope back on the main desk for it to be used by others at this time.

---

128. PROCEDURAL ITEM - NO WRITTEN RESPONSE

Now we are ready for the laboratory experiment. You will notice the materials and equipment are placed in the work area for you. Check over the following list and make sure you have these materials and equipment with which to work. The items numbered in the list correspond with the numbers on the materials and equipment which you see. Take these items to an area designated for you to work. Check the time; if you do not have approximately fifteen minutes to get started on the experiment, then spend the remaining portion of the period reviewing and studying the frames you have just covered. Allow five minutes

to put the materials back in place in order to be ready for your next class. For those of you who have already studied all the frames up to this point, the following items listed as 7-11 will be needed in addition to those you have already used. If a microscope is not available to you at this time, and you have not studied frames 49-127, you will need items 6-11 now.

1. A microscope
2. A microscope slide
3. A small strip of graph paper with "a" typed on it
4. Lens paper
5. A piece of typing paper
6. Millimeter rule
7. Foot rule
8. Yardstick
9. A 25-ft carpenter's tape (Do not remove this until you are ready to use it. Put it back immediately for other students to use.)
10. A penny
11. A paramecium and eye dropper (Don't take this to your working area until you are ready to measure it.)

---

129. Measure first your piece of typing paper with the foot rule, both width and length. What is the width in inches? ______________ Length in inches? ______________

8½ or 8.5 inches
11 inches

---

130. Now using your millimeter rule, measure the width and length of the same sheet of paper. What is the width in millimeters to the nearest whole number? ______________
What is the length in millimeters? ______________

216 mm.
279 mm.

---

131. A micron is another unit of measurement in the Metric System. A micron is 0.001 of a millimeter. Another way of thinking of its relationship is that 1,000 microns equal one millimeter. What is the <u>width</u> of the typing paper in microns?
____

216,000 microns

---

132. What is the <u>length</u> of the same piece of paper in microns? ______________

279,000 microns

---

133. Recall the relationship of centimeters to millimeters. Ten millimeters equals one centimeter. Convert your measurements for the typing paper into centimeters. The width would be 216mm divided by ten, equals _______ centimeters. The length would be ____________ centimeters.

21.6 cm.
27.9 cm.

---

134. Which measurement would be the most accurate? _________

millimeter; it would yield a smaller unit

No, the sheet is large enough to be fairly accurate with larger units of measurement.

135. Do you see any need for measuring a sheet of typing paper in microns? Why or why not? (Own words) ________

19 mm.

136. Next measure the diameter of your penny in millimeters. What is its diameter in millimeters? (Round off to the nearest whole.) ________

3/4 inch or .75 inch

137. Measure the diameter of your penny in inches. What is its diameter in inches? ________

19,000 microns

138. What is the diameter of the penny in microns?

1.9 cm.

139. What is the diameter of the penny in centimeters?

Yes, ½ inch would equal .64 cm. so 3/4 inch would equal 1.92 cm.

140. One inch equals 2.54 centimeters. A centimeter is approximately 2½ times as small as an inch. Check your answer for frame 137. Does that seem to be correct for the diameter of your penny if it was 3/4 inch across? Explain your reasoning. ________

micron

141. What unit of measurement would probably be the most accurate for the diameter of the penny? ________

No

142. Would you be able to resolve or see 0.001 millimeter with your naked eye? ________

millimeter

143. What unit would probably be the most accurate for the diameter of the penny using only your naked eye? ________

Answers will vary with heights.

144. Have a classmate help you measure your body's height with the yardstick. Standing with your body erect beside the wall or the door in your room, have him place the yardstick flat on top of your head. He should hold the point of contact on the wall or door with his finger. You may then measure the distance from the floor to his point of contact. What is your height in inches? ________

Answers will vary with heights.

145. Convert this figure to millimeters. What is your height in millimeters? (Remember one inch equals 25.4 millimeters.) ________

146. Convert your height to centimeters. You may either multiply your inches by 2.54 cm. or the millimeters can be divided by ten. Double check both ways to see if your answer is correct. Your height in centimeters is ________.

Answers will vary with heights.

147. What is your height in microns? ________

Should have multiplied height in millimeters x 1000.

148. Do you think there is any practical use for measuring people in microns or millimeters? Why or why not? ________

No, knowing a person's height in feet or inches is satisfactory.

149. Using the yardstick, measure the width and length of your classroom in yards. What is its width in yards? ________ Length in yards? ________

Answer depends upon classroom

150. Using the foot rule, measure the width and length of your classroom in feet. What is the width in feet? ________ Length in feet? ________

Answer depends upon classroom

151. Which standard measured the room more accurately, the yardstick or the foot rule? ________

Yardstick

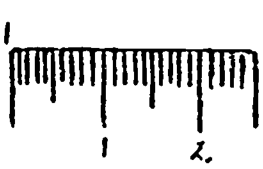
152. What is the width of your classroom in inches? ________ Length in inches? ________

Answer depends upon classroom

153. Convert the width and length to meters. Recall that 39.37 inches equal one meter. What is the width of your classroom in meters? ________ Length in meters? ________

Answers to frame 152 should be divided by 39.37 inches

Inch
Millimeter
Centimeter



154. In case you are somewhat confused at the "newness" of the Metric System, review by using the figure at the left. It is exactly one inch long. You will be asked again to convert inches to centimeters. Do you understand why one must divide 2.54 cm. into the number of inches you are converting to obtain the number of centimeters in a given number of inches? ________

155. How many millimeters are in an inch? (See figure at the left.) ________

25

156. How many millimeters equal one centimeter? (See the figure at the left.) ________

10

Answers should be 2.54 times the answers to frame 152	157. Convert the width in inches to centimeters.________ Convert the length in inches to centimeters. ________
Answers should be 10 times the answers to frame 157	158. Convert the width in centimeters to millimeters. ________ Convert the length in centimeters to millimeters. ________
Answers should be 1000 times the answers in frame 158	159. Convert the width in millimeters to microns. ________ Convert the length in millimeters to microns. ________
No	160. Do you think it would be useful to measure something as large as your classroom in microns? ________
Fraction of an inch or a millimeter	161. If you were trying to cover the classroom floor with tile blocks, how accurate do you think you'd need to be to fit the last piece in? ________

162. PROCEDURAL ITEM - NO WRITTEN RESPONSE REQUIRED

a. Using the 50-ft. carpenter's tape, measure the length and width of a portion of your school grounds. Your teacher will designate the particular portion. If the area is not rectangular, try to approximate a rectangle. Measure its greatest length and greatest width.

b. You will need a partner in this exercise. Select a classmate who seems to be at the same place you are in your experiment.

c. Ask permission of your teacher to leave the classroom.

d. When outside Student A can hold the tape apparatus while Student B travels a distance of 50 feet with the tape itself. Student A must stand firmly without moving while holding the tape apparatus. Student A can then come to the spot 50 feet ahead where student B is. The process is begun all over again until the length is completely measured. BE SURE AN ACCURATE COUNT OF TAPE LENGTHS IS KEPT. If, for example, it takes ten lengths of the carpenter's tape to measure the length of the school grounds, this would mean 10 x 50 feet or 500 feet is the length.

e. Measure the width of the school ground portion in the same way.

Answer depends upon school grounds	163. What is the length of your school grounds in feet? ________ What is its width in feet? ________

Answer depends on school grounds

164. Convert the length into inches. __________ Convert the width into inches. __________

Answer depends on school grounds

165. What is the school grounds length in meters? One meter equals 39.37 inches.) __________ The width in meters is __________.

Answer depends on school grounds

166. Convert the length measurement into yards. __________ Convert the width measurement into yards. __________

Answer depends on school grounds

167. What is the length of the school grounds in centimeters? __________ What is the width of the school grounds in centimeters? __________

Answer depends on school grounds

168. Convert the length to millimeters __________. Convert the width to millimeters __________.

Answer depends on school grounds

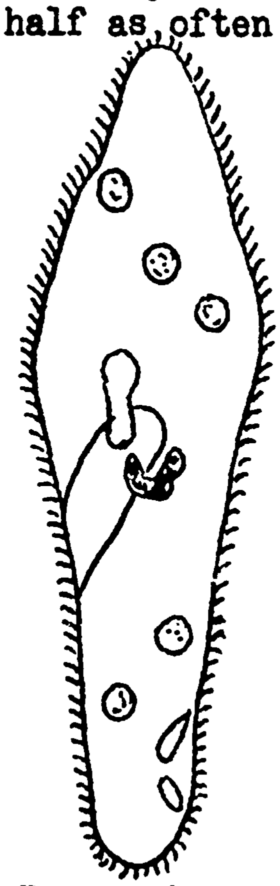
169. What is the length of the school grounds in microns? __________ What is the width in microns? __________

Fairly accurately but having to replace the length of the tape quite often would introduce human error.

170. How accurately do you think you meas‿ed the school grounds with a 50-ft. carpenter's tape? __________

Yes, the tape would have been replaced only half as often

171. Do you think a 100-ft. carpenter's tape would have given you more accuracy? Explain your answer. __________



Paramecium

172. PROCEDURAL ITEM - NO WRITTEN RESPONSE REQUIRED

a. Now you will need the microscope. Set it up ready to use. Look for the number of the microscope which you previously used. The number is recorded in frame 126. If you have not studied frames 49-127, do so now. Then come back to this section.

b. Take a microscope slide, and using an eye dropper put a drop or two of water in the middle of your slide from the infusion culture containing paramecia or some other ciliate protozoan.

c. Focus the microscope properly on low power and try to locate a one-celled animal that resembles the figure at the left. An active paramecium will look like a white dot darting across your field of vision.

d. Place a sheet of typing paper just to the right of the microscope base if you are right-handed. Place it to the left if you are left-handed.

e. Now as you observe the paramecium with your left eye (if right-handed) or right eye (if left-handed), visualize with your other eye the same image on your typing paper that you see through the microscope. Try to locate the paramecium when it is not too active and trace its image.

Answer depends upon size of paramecium	173. Measure the image of your paramecium. What is its length in millimeters? ________
Answer depends upon size of paramecium	174. What is the correct measurement of your paramecium? To determine it, divide the degree of magnification you obtained (frame 125) into the length of the image of your paramecium. What is the length of your paramecium in millimeters? ________
Answer depends upon size of paramecium	175. Your answer is probably a decimal figure, much less than one. Convert your answer to microns. Remember one millimeter equals 1000 microns. ________
Not practical in any of the three cases. An extremely small unit is needed	176. How practical do you think it would be to measure a paramecium in meters or yards? ________ In feet? ________ In inches? ________ Why or why not? ________
Microscopic measurement can be made more accurately	177. Can you see why the unit of measurement called the "micron" was invented? Explain why you think it was necessary. ________
Yes, the smaller the object the smaller the unit needed	178. Do you see a relationship between the <u>size</u> of the object being measured, and the size of the <u>unit</u> needed for necessary accuracy? ________
Yes, the more accuracy desired the smaller the unit that should be used	179. Do you see a relationship between the desired degree of accuracy and the size of measurement units used? Explain. ________
	180. When you are through with the microscope, please do the following so that the next person to use the microscope will be able to start off as you did.

a. Position the microscope so that it is again in an upright position by holding the base and applying pressure on the arm.

b. Shift to low power.

c. Take the slide off the stage.

d. Return the clamps to the original position.

e. Turn the coarse adjustment away from you until it is all the way down, and then turn it back toward you so that the low power objective is about one inch from the stage.

f. Set the diaphragm wheel at "1" by turning the diaphragm right.

g. If the microscope has an electric power source, unplug it and wrap the cord around the base.

h. Wipe off any water on the stage or surrounding laboratory table.

i. Put the cover on the microscope if it has one.

j. Clean off the slide and the cover slip.

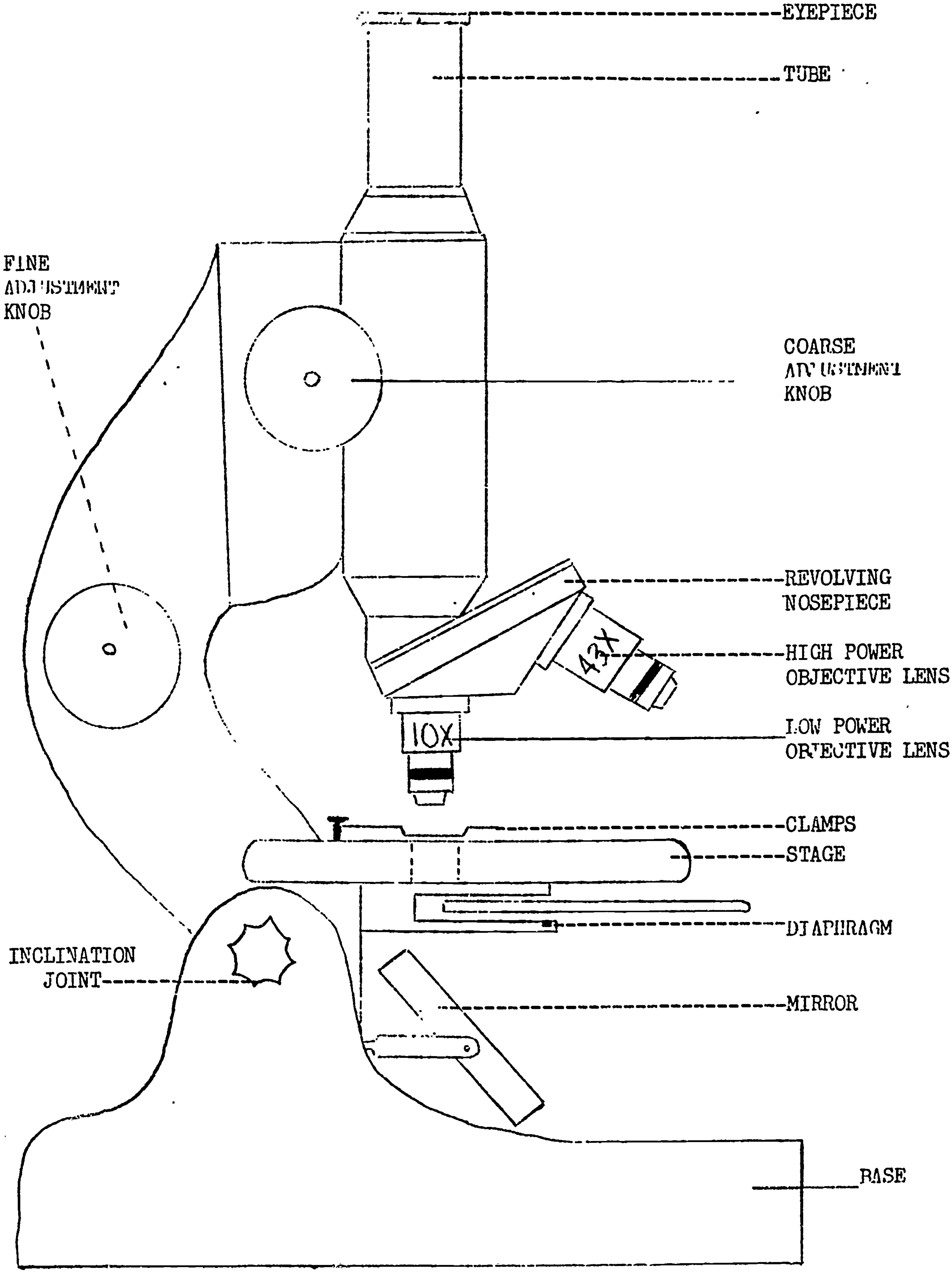
FURTHER INVESTIGATIONS

181. If you have extra time you might be interested in considering the following questions. How important is it that you know about the 50 cents if (a) you have only $1.50 when you are ordering dinner at a restaurant? (b) you have $151.50 in your checking account at the bank when you wish to buy an article of clothing? (c) you have $5,151.50 in your savings account when you wish to make a down payment on a house? (d) a proposed large expenditure by the company for which you work is $55,151.50? (e) an intercontinental ballistics missile costs $5,151,151,151.50? Why?

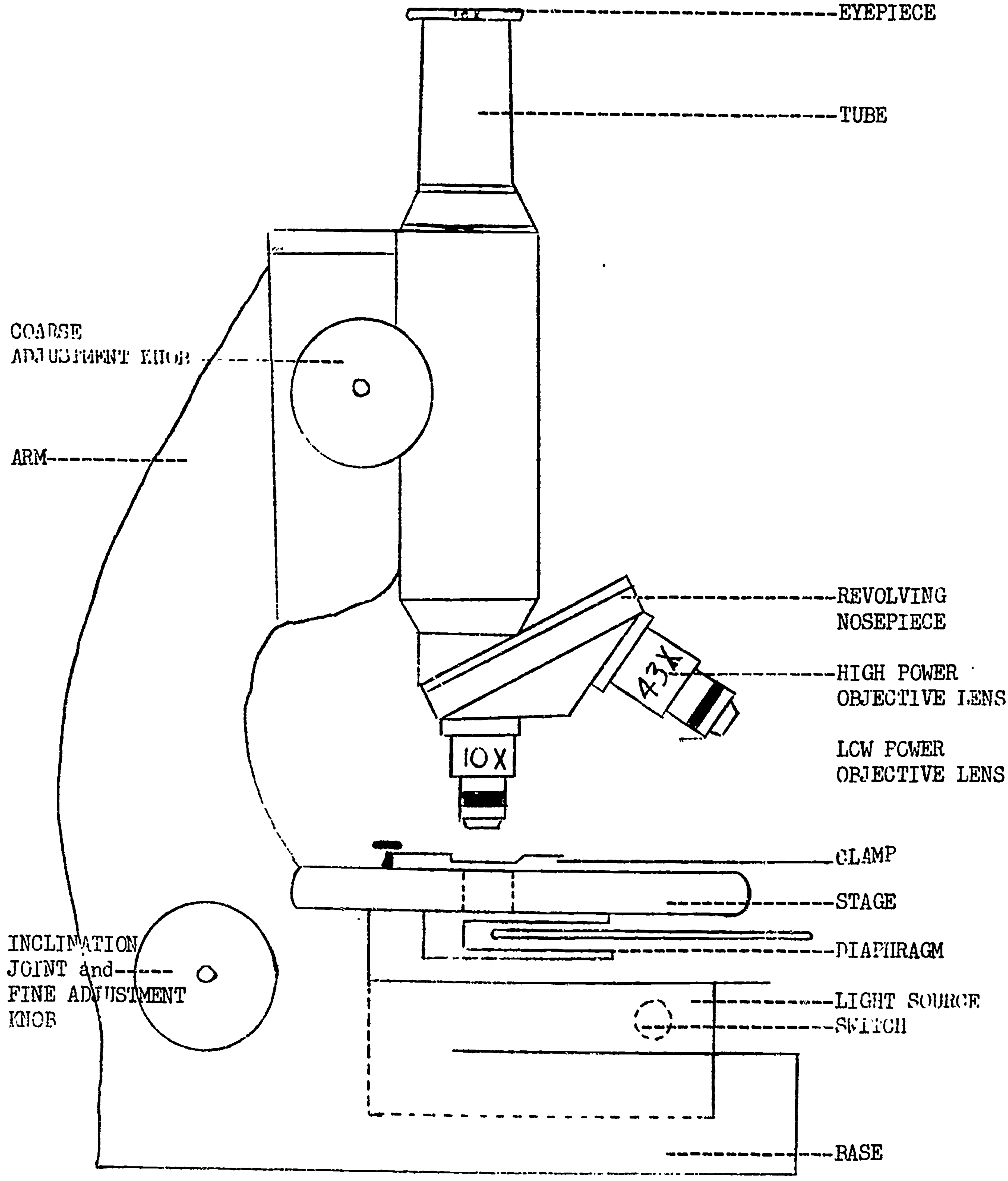
---

182. If you have time remaining in the period begin on the next programmed lesson. File this lesson in a safe place so that you may review it later.

MICROSCOPE WITH MIRROR AS A LIGHT SOURCE



MICROSCOPE WITH AN ELECTRIC LIGHT SOURCE



MEASUREMENT AS AN EXPRESSION OF RELATIONSHIP:

A SIMPLE BALANCE

Section__________ Name______________________________

1. In the laboratory you will often hear the words, "quality" and "quantity" or "qualify" and "quantify". Quality means the degree of excellence or characteristic nature of a substance. If something were of very fine quality it would have a high degree of ______________.

excellence

2. Quality also refers to the basic nature, characteristic of a substance. Curiosity may be an outstanding quality which you possess. The quality, curiosity, would be characteristic of your basic ______________.

nature

3. If you saw a microscope priced $100.00 and another priced $300.00, you could assume that the $300.00 microscope was of a finer ____________ than the $100.00 microscope.

quality

4. Suppose you are a person highly interested in science. Scientific interest would be a ______________ of your basic nature.

quality

5. "Quantity" is defined as the amount of a substance. Suppose you were asked to use 10 ml. of a solution in an experiment. The 10 ml. of the solution would represent the ____________________ used.

quantity

6. If you were asked to use a 10 ml. solution and a 20 ml. solution, which amount would be the largest quantity?

20 ml.

7. In our last experiment when we worked with leaves of Ulmus americana, the number of leaves used for a representative sample represented a certain (quality/quantity) ____________________ of leaves.

quantity

8. Quantity is really that property (trait) of anything which can be determined by measurement. We measured the length of leaves; therefore, ____________ is a quantity.

length

9. To state it another way, units of measurement (that is, yards, millimeters, inches, etc.) are actually expressions of relationship between two quantities. We compared the length of a millimeter to the length of a leaf. The relationship of the millimeter to the leaf was between two ______________________________.

quantities

xcellence
ature
mount

10. Quality has to do with the degree of ______________ or the basic ____________ of a substance, while quantity designates the ______________ of a substance.

---

11. In the last experiment we learned that units of measurement are man-made. They are not scientific laws scientists discovered, and could be no other way. Units of measurement are __________-__________________.

an-made

---

12. The metric system was worked out at the time of the French Revolution. The meter was set as one ten-millionth part of the distance from the equator to the north pole. All other quantitative measurements were based on it, worked out in multiples of ______________________.

en

---

13. The only reason that we use ten, however, is that we have ten fingers. The ancient Babylonians used "twelves", and the Mayas "twenties". The Mayas must have based their number system on ten fingers and ten ______________.

oes

---

14. Modern electronic calculators use a numbering system based on "two", since only two alternatives are possible in any particular case. No type of numbering system is a scientific law; all are __________-______________.

an-made

---

15. It is possible to set up a system of measurement of your own. To do so will help you to think of measurement as a standardized but artificially-based expression of a set of relationships. An expression of relationship between two quantities is called a unit of ____________.

easurement

---

16. When you have done this, in today's experiment, you can translate your system into standard units. Recall that a standard is a representation of a unit of measurement. A meterstick represents a certain measurement and is thus called a ______________________.

standard

---

17. PROCEDURAL ITEM - NO WRITTEN RESPONSE REQUIRED

We are now ready to set up a system of measurement. You will notice the materials and equipment are placed in the laboratory for you. Check over the following list and make sure you have these supplies and equipment with which to work. The items numbered in the list correspond with the numbers on the materials and equipment which you see. If there are fifteen minutes remaining in the period, take these items to a designated work area. Allow five minutes to get things put away and in order for your next class. If you have less time remaining, perhaps it would be wise to review the frames you just covered for the closing time.

1. Yardstick (with your name on it unless you did not notch yours previously)
2. Hacksaw blade (only if you have not previously notched your yardstick)
3. Two frozen juice cans with holes punched on 2 sides
4. One frozen juice can without punched holes, containing 120 BBs
5. Two pieces soft wire six inches long
6. Ten pennies
7. String - length determined by where your support for the suspension of your balance is located
8. Wax pencil
9. Laboratory scales (Leave the scales positioned where they are. They are for use in the event you want to use them in testing an hypothesis.)
10. Support for suspension of balance (Ask your teacher about this.)

---

18. PROCEDURAL ITEM - NO WRITTEN RESPONSE REQUIRED

As you proceed, read each frame completely before you begin working. That is, read a., b., c., etc. under the frame, and then go back to a. and begin working.

---

19. PROCEDURAL ITEM - NO WRITTEN RESPONSE REQUIRED

a. If you have not already notched your yardstick, use the hacksaw blade to make a notch across the top of the yardstick at its exact midpoint. The notch should be deep enough to hold the string.

b. Using a piece of string about six inches long, or as long as you need, tie it around the stick with the knot lying in the notch, leaving the two ends of even length. Be sure your knot is lying in the notch.

c. Tie the ends of the string together, and hang the stick from the support for your balance.

---

20. Does it balance, or is one end higher than the other?

Answer depends upon results

____

____

21. PROCEDURAL ITEM - NO WRITTEN RESPONSE REQUIRED

a. If you have not already done so at home, with the hacksaw blade make shallow notches across the top of the yardstick at each quarter-inch. Make the notches straight and uniform. Saw easily since this is soft wood, and chips come out rather easily between quarter-inches. If while sawing this

should happen, use scotch tape to fasten the chip back in place.

b. Suspend the stick again.

Answer depends upon results; some notches could have been more deeply cut on one side leaving less weight on one side

22. Is it as well-balanced as before?______
If it isn't, what do you think has happened?______

---

23. PROCEDURAL ITEM - NO WRITTEN RESPONSE REQUIRED

a. Pass a six-inch piece of wire through the holes in each can.

b. Tie the ends together in such a way that the can may be suspended from the stick, and moved along from one notch to another.

c. Suspend the cans from the last notch at each end of the stick.

Answer depends upon results

24. Do they balance?______

---

25. PROCEDURAL ITEM - NO WRITTEN RESPONSE REQUIRED

Reverse the cans.

Answer depends upon results

26. Do they work as well regardless of the end from which they are suspended?______

27. PROCEDURAL ITEM - NO WRITTEN RESPONSE REQUIRED

a. Either the stick or the cans or both may not be completely balanced. Select one can for the right side and one for the left side. Mark them with a wax pencil using "L" for "left" and "R" for "right", so that you can use them this way from this point on.

b. PLEASE BE VERY CAREFUL IN HANDLING THE BBs or you shall find you are spending most of your time chasing BBs. Open only ONE package very carefully and place them in your third frozen juice can.

c. Add BBs to the can on the side that hangs highest, to bring it into balance.

d. Write down the number of BBs used, and leave them in the can. They constitute the necessary <u>correction factor</u> at this point.

Answer depends upon results

38. The correction factor was, in this case, the number of BBs necessary to balance your cans. What was the amount of your correction factor? (#) ______________ BBs.

---

29. PROCEDURAL ITEM - NO WRITTEN RESPONSE REQUIRED

Add 50 BBs to each can. Count them very carefully and try to keep them from rolling over the floor.

Answer depends upon results

30. Are they still in balance? ______________

Answer depends upon results

31. Is the correction factor still the same? ______________

You could have counted incorrectly, or the BBs might not have been of uniform weight.

32. If not, can you suggest a reason why? ______________

---

hypothesis

33. Hypothesis is another word which scientists often use. It means "an intelligent guess". In frame 31 you were asked to make an intelligent guess or an ______________.

---

34. PROCEDURAL ITEM - NO WRITTEN RESPONSE REQUIRED

a. Test your hypothesis of frame 31, if you can think of a way of doing so.

b. In any case, adjust your correction factor, if necessary, by adding or subtracting one or more BBs, and proceed.

c. Be sure to keep a record of what you have done.

Answer depends upon results

35. There are now (#) ______________ BBs in your left can.

Answer depends upon results

36. There are now (#) ______________ BBs in your right can.

Answer depends upon results

37. Your second adjustment factor is the number of BBs you added or subtracted after adding 50 BBs to each can. The amount of your second adjustment is plus or minus what number of BBs? ______________

---

38. PROCEDURAL ITEM - NO WRITTEN RESPONSE REQUIRED

a. Move both of the cans containing the BBs toward the center, one quarter-inch at a time.

b. Carefully add or subtrect BBs as necessary, to balance them each time. Keep a record of the number of BBs and the points where any changes are made. Record the correction on a separate sheet of paper. Suggestion: the first quarter-inch moved could be one, the second quarter-inch, two, etc.

c. Bring them as close together as you are able without the cans touching.

---

39. Are additional corrections necessary as you proceed?

Answer depends upon results

40. If adjustments are necessary, can you suggest a reason why?

BBs might not be uniform or the notches might not be uniform

41. Test your hypothesis if you can devise a way of doing so.

42. PROCEDURAL ITEM - NO WRITTEN RESPONSE REQUIRED

a. Carefully remove all BBs from the cans, and balance the cans at a point three inches (12 quarter inches) from the mid-point.

b. Predict or make an hypothesis as to what your correction factor will be at that point.

c. Carefully add BBs to serve as a correction factor to the extent necessary.

---

43. Is the correction factor at this point, using the empty cans, what you would have predicted it to be?

Answer depends upon results

44. If not, can you suggest a reason why?

Answer depends upon results

45. Test your hypothesis if you can.

46. PROCEDURAL ITEM - NO WRITTEN RESPONSE REQUIRED

a. Place a penny in the left-hand can.

b. Carefully add BBs to the right-hand can to balance the penny.

Answer depends upon results	47. How many BBs does it require?
	48. PROCEDURAL ITEM - NO WRITTEN RESPONSE REQUIRED a. Add a second penny on the left-hand side, and move the right-hand can out from the center one quarter-inch. b. Add BBs as necessary to achieve a balance. c. Record the data.
Answer depends upon results	49. How many BBs were required to balance the addition of the second penny?
	50. PROCEDURAL ITEM - NO RESPONSE REQUIRED a. Continue to add pennies one at a time until you have added ten, each time moving the right-hand can out from the center one quarter-inch with the addition of each penny. Add BBs each time as necessary to achieve a balance. b. On a separate piece of paper, continue to record the data of each correction factor or the weight of each penny, each time you move the right-hand can.
measurement	51. You are now weighing the pennies using "quarter-inches" and "fractions of quarter-inches" as weight units instead of ounces or grams as the case may be. The fractions are expressed in terms of BBs. Thus a penny may weigh "one quarter-inch and two BBs". Your "quarter-inches" and "fractions of quarter-inches" are man-made units of ______.
Answer depends upon results	52. Is the weight of each additional penny the same, as you move from near the center toward the right end of the stick?
Answer depends upon results	53. If there are differences, are they consistent as you move along; that is, is there a trend or regular pattern of change?
Older pennies could be worn more than others; some might have less copper; BBs could vary in size	54. If all your pennies did not weigh the same, can you think of some reasons for this?

55. PROCEDURAL ITEM - NO WRITTEN RESPONSE REQUIRED

Test your hypothesis if you can think of a way to do so.

56. Determine the average weight of a penny by dividing the number of pennies, ten, into the total number of BBs in your right-hand can, and into the number of quarter-inches away from the center. For example, if your ten pennies weighed ten quarter-inches and 50 BBs, the average weight would be one quarter-inch and five BBs.

Answer depends upon results

What is the average weight of one of your pennies in "quarter-inches" and "fractions of quarter-inches"?________

57. PROCEDURAL ITEM - NO WRITTEN RESPONSE REQUIRED

Try <u>beginning</u> farther from the center.

58. PROCEDURAL ITEM - NO WRITTEN RESPONSE REQUIRED

a. Think of a way to test whether the ages and relative wear of the pennies make any difference if you can.

b. Think of other ideas to test.

59. PROCEDURAL ITEM - NO WRITTEN RESPONSE REQUIRED

a. Now determine the value of a "quarter-inch" in terms of BBs.

b. Start with empty cans at the twelfth notch (three inches) from the center on each side.

c. Balance the cans again, using whatever correction factor is necessary.

d. Put 50 BBs in each can to start.

e. Move the right-hand can out one quarter-inch at a time, and add BBs to the left-hand can as necessary to maintain a balance.

f. Use the blank space at the left of this page to record the number of BBs added to balance each quarter-inch the right-hand can is moved.

Answer depends upon results

60. Is the number the same each time?________

Answer depends upon results

61. Is there a trend?

62. PROCEDURAL ITEM - NO WRITTEN RESPONSE REQUIRED

Determine the average value of a "quarter-inch" by dividing the total number of BBs added to the left-hand can (after the initial 50 BBs in each can), by the number of quarter-inches you have moved the can from the starting point at three inches.

Answer depends upon results

63. What is the average value of a "quarter-inch" in terms of number of BBs?

Answer depends upon results

64. Are your results consistent with those that you obtained with the pennies?

65. If not, suggest a possible explanation.

66. Test your hypothesis if you can devise a way of doing so.

The midpoint at 18 inches.

67. A lever can be compared to the operation of a balance. A lever is a device consisting of a bar turning about a fixed point, the <u>fulcrum</u>, using power or force applied at a second point to lift or sustain a weight at a third point. What would be the position of the fulcrum on your simple balance?

68. This frame is a homework assignment for you to do tonight. Try to think of ten questions having to do with the <u>idea of measurement as an expression of relationship</u>. Please hand this assignment in at the beginning of class tomorrow. The following questions will perhaps give you some ideas:

> Is one morning of plowing a good way to measure an acre?
> If there were only millimeters how much measuring would be done of big objects?
> What does standard measurement have to do with a ruler?

FURTHER CONSIDERATIONS:

69. It might be a good idea at this point to repeat the entire experience, using new materials throughout, to see if results are the same or comparable.

70. Both equal arm and unequal arm balances can be used to weigh quantities. Ordinary laboratory balances are equal arm balances. Unequal arm balances were formerly in use on farms and elsewhere for weighing sacks of grain and other quantities. They were called "steelyards".

What would you say as to the amount of error in your balance? Work out the equivalence of the quarter-inch unit on your balance in grams. Number the notches on each end of the stick. Start with the first notch at each side of the center notch as "1", and number toward each end. Weigh various objects with your balance. Check the accuracy of the figures obtained by weighing the same objects on a laboratory balance.

---

71. How does a spring type scale work? Which do you think would be more likely to develop inaccuracies or errors, a spring type scale or a balance type? Why?

---

72. What are the relationships between weight, mass and density? What is meant by specific gravity? What standard is used for expressing it? How is it possible to calculate the weight of the earth? On what basis is the statement made that the moon has a lower density than the earth? What determines the force of gravity? Why would a man weigh less on the moon's surface than on the earth? What about Mars?

---

73. If you have time remaining in the period begin on the next programmed lesson. File this lesson in a safe place so that you may review it later.

SCIENCE WORK SHEET

Section________________ LESSON 1 Name____________________

The questions below are designed to aid you in understanding the material to be learned. After you have answered the questions, your paper will be checked and given back to you for class discussion. Please be thorough in your discussion of a question unless the question asks for only one word. After each statement or question, you will find page numbers, and a capital letter in parentheses. The capital letter is a code for the resource book, and on the page numbers listed you should find the answers to the questions. Don't forget the index to a book, the glossary, the dictionary, and the encyclopedia can also be helpful.

TODAY'S BASIC SCIENCE	- A	SCIENCE IN THE SPACE AGE	- E
SCIENCE LIFE 5	- B	NEW DYNAMIC BIOLOGY	- F
SCIENCE, A WAY TO SOLVE PROBLEMS	- C	SCIENCE, A SEARCH FOR EVIDENCE	- G
SCIENCE AND YOUR FUTURE	- D	SCIENCE LIFE 6	- H

1. What is meant by the interaction or interdependence of matter? (pp. 364-365, 386, 428-429-A)

2. Define and discuss "metabolism". (pp. 301-307-F)

3. Define "microscopic organism" or "microorganism". (pp. 124-125-A; pp. 78-90-F; pp. 382-386-G; p. 50-C)

4. Explain how "fermentation" takes place. (pp. 112-115-F; pp. 372-373-G)

5. Define "carbohydrate". Give two examples of carbohydrates. (pp. 118-121-E; pp. 89-92-A; p. 297-F; pp. 336-337-G; p. 120-H; p. 25-C; p. 18-B)

6. What is a base? (pp. 80-82-D; pp. 142-143-C)

7. Define an acid. (pp. 45-47-E; pp. 80-82-D; pp. 142-143-C)

8. Define "gradient". (Check your dictionary or encyclopedia.)

SCIENCE WORK SHEET
LESSON 2

Section ____________ Name ________________

Proceed with this lesson exactly as you did with Lesson 1. Remember the glossary, the index to a book, the dictionary, and the encyclopedia can also be helpful.

TODAY'S BASIC SCIENCE	- A	SCIENCE IN THE SPACE AGE	- E
SCIENCE LIFE 5	- B	NEW DYNAMIC BIOLOGY	- F
SCIENCE, A WAY TO SOLVE PROBLEMS	- C	SCIENCE, A SEARCH FOR EVIDENCE	- G
SCIENCE AND YOUR FUTURE	- D	SCIENCE LIFE 6	- H

1. Give a good definition of "matter". (p. 51-A; pp. 50-53-D; p. 88-B; p. 140-C; p. 42-G)

2. Discuss the classification of matter. (p. 61-A; pp. 50-51-D; p. 88-B; pp. 42-43-G)

3. What is an element? (p. 61-66-A; pp. 58-59, 69-71-D; p. 78-B; pp. 140-141, 145-146-C; p. 42-G)

4. What is a compound? (p. 67-68-A; pp. 69-72-D; p. 116-C; p. 80-B; p. 42-43-G)

5. Distinguish between "substance" and "pure substance". (p. 61-A; p. 44-D)

6. Distinguish between molecules and atoms. (p. 64-E; pp. 62-68-A; pp. 52-53-D; pp. 137-139-C; p. 88-B)

7. Distinguish among solvent, solute, and solution. (pp. 71, 183-D; pp. 89-90-B; pp. 69-70, 223-233-A)

8. What is analytical chemistry? (p. 283-A; pp. 84-85-D; pp. 140-141-C; p. 120-E)

9. What is chromatography? (p. 284-A; pp. 182-183-D)

10. Discuss paper chromatography. (p. 284-A; pp. 182-183-D)

SCIENCE WORK SHEET
LESSON 3

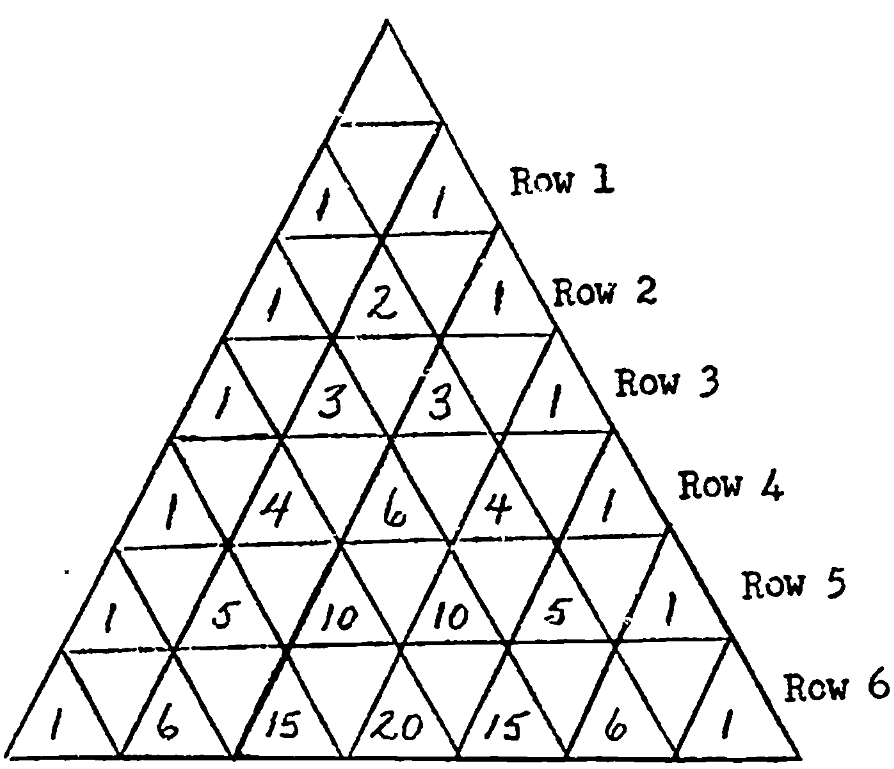
Section ____________ Name ______________________

1. Read pp. 217-219 in TODAY'S BASIC SCIENCE, in preparation for this exercise.

2. For what is Blaise Pascal noted?

3. What is Pascal's Triangle?

4. Now let's see how we can apply Pascal's key to our lesson on normal curves in nature. Row 1 of the triangle can be interpreted to mean that one coin was tossed twice. The law of probability states that it is probable that one toss would be heads and one tails.



Row 2 can mean that two coins were tossed twice. There are four possibilities:

(1) 2 heads
(2) 1 head and 1 tail
(3) 1 tail and 1 head
(4) 2 tails

The middle two possibilities are really the same. The results could be expressed as they are in the triangle as 1:2:1.

5. Analyze Row 3, if it represents three coins tossed one after another for eight tosses. What are the possible results you could obtain?

(1) ________heads
(2) 2________ 1________
(3) 1 head, 1 tail, 1 head
(4) 2 heads, 1 tail
(5) 2 tails, 1 head
(6) 1________ 1 head, 1________
(7) 2________ 1________
(8) 3 tails

Which possibilities are the same? Give the specific numbers such as (2), (3), (4), etc. ______________________

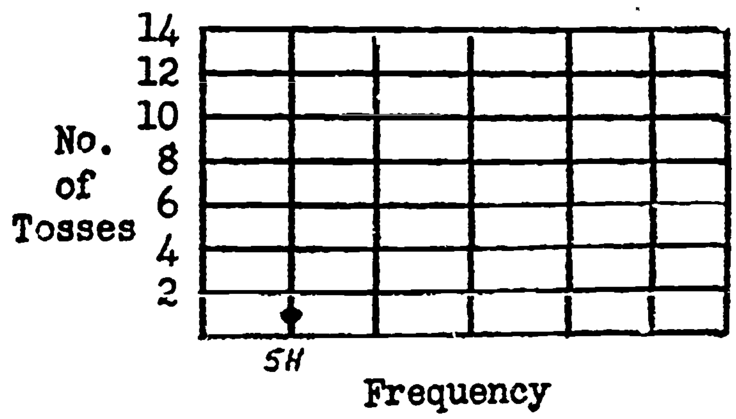
6. These events can be summarized as 1:3:3:1. Fill in what each number represents:

Number of Tosses	Results
1	____________
3	____________
3	____________
1	____________

7. Analyze Row 5, if it represents 5 coins tossed 32 times. Do this on scrap paper until you think you can fill in the blanks.

Number of Tosses	Results
1	5 heads
5	
10	
10	
5	
1	

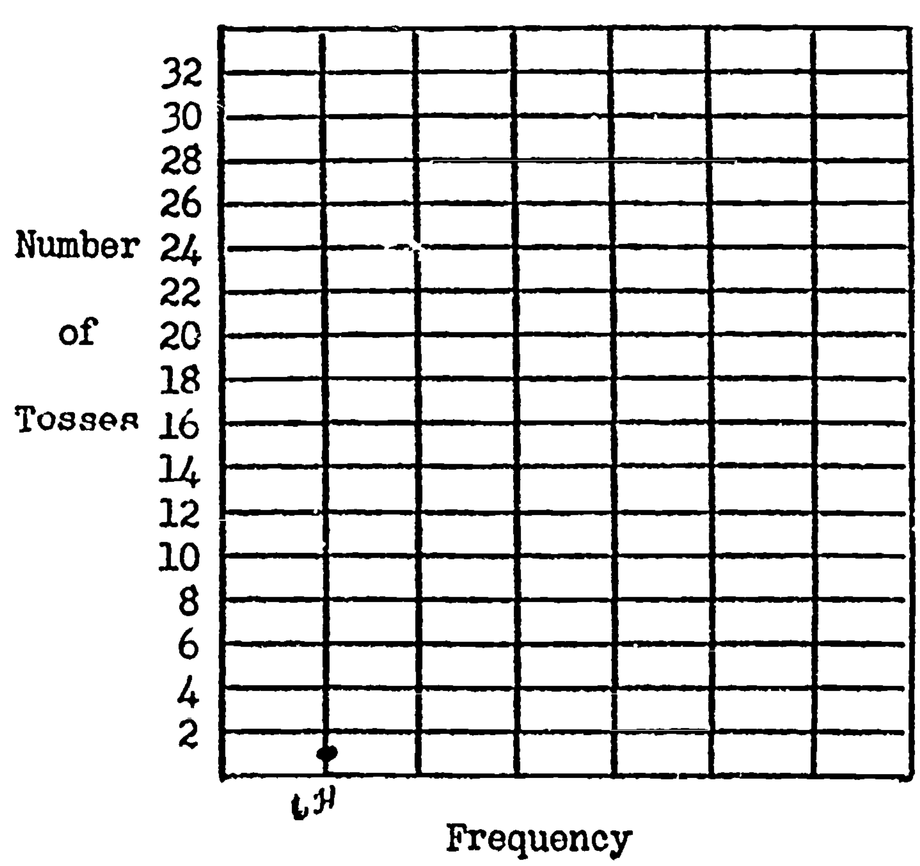
8. Plot your results on the graph at the right. The first one is done for you. Connect your dots with lines. Your results should demonstrate a normal curve. Do they? ______________



9. Analyze Row 6 in the same way. This represents data from tossing six coins sixty-four times. Fill in the blanks.

Number of Tosses	Results
1	
6	
15	
20	
15	
6	
1	

10. Plot your results on the graph provided. The first one is done for you. Again, your data should have approximated a normal curve. Coin tossing is only one of many, many events that demonstrates a normal curve. You might try tossing coins at home tonight and compare your results with the probabilities indicated by the <u>Pascal Triangle</u>. Don't expect to obtain the exact results. Pascal's probabilities represent an average derived from a thousand or more tosses. But your results may come close to Pascal's.



SCIENCE WORK SHEET

Section________________ LESSON 4 Name____________________

Proceed with this lesson exactly as you did with previous lessons.

TODAY'S BASIC SCIENCE	- A	SCIENCE IN THE SPACE AGE	- E
SCIENCE LIFE 5	- B	NEW DYNAMIC BIOLOGY	- F
SCIENCE, A WAY TO SOLVE PROBLEMS	- C	SCIENCE, A SEARCH FOR EVIDENCE	- G
SCIENCE AND YOUR FUTURE	- D	SCIENCE LIFE 6	- H

1. Define taxonomy. (p. 154-A; p. 56-F; p. 296-E)

2. Define classification. (p. 153-A; pp. 97-105-F)

3. What did Carolus Linnaeus contribute to the study of living things? (pp. 153-158-A; pp. 14-15-G; p. 97-F)

4. What are the seven levels of plant and animal classification? (pp. 153-158-A; pp. 97-105-F)

5. The new classification tables place animals into ____________ phyla and plants into ______________ phyla. (p. 157-A)

6. In what ways does a <u>species</u> differ from a <u>genus</u>? (pp. 153-158-A; pp. 14-15-G; p. 101-F)

7. Why do scientists prefer to use Latin in giving scientific names to plants and animals? (pp. 153-158-A; pp. 14-15-G)

8. Define sample as it pertains to scientific investigation. (p. 22-G)

SCIENCE WORK SHEET

Section_______________ LESSON 5 Name_______________

Proceed with this lesson exactly as you did with previous lessons.

TODAY'S BASIC SCIENCE	- A	SCIENCE IN THE SPACE AGE	- E
SCIENCE LIFE 5	- B	NEW DYNAMIC BIOLOGY	- F
SCIENCE, A WAY TO SOLVE PROBLEMS	- C	SCIENCE, A SEARCH FOR EVIDENCE	- G
SCIENCE AND YOUR FUTURE	- D	SCIENCE LIFE 6	- H

1. What are the two widely used systems of measurement? (p. 44-A; p. 18-G)

   What are the basic units of each? (p. 44-A; p. 18-G)

2. Explain why the Metric system is preferred by scientists. (p. 44-A; p. 18-G)

3. What is a meter? How many inches does it equal? (pp. 44-45-A; p. 19-G)

4. How many centimeters equal one meter?_____________ (p. 45-A; p. 19-G)

5. How many millimeters equal one meter? _____________ How many millimeters equal one centimeter? _____________ (p. 45-A; p. 19-G)

6. How large is a <u>micron</u>? (p. 81-F)

7. Define <u>liter</u>. If "milli" means "one thousandth", how many <u>milli</u>liters would equal a liter? (p. 19-G)

8. How many centimeters equal one inch? (p. 19-G)

9. How is the magnifying power of a compound miscroscope determined? (p. 44-A)

10. What is a paramecium? Where are paramecia found? (pp. 126-127-A; pp. 88-89-F; p. 298-E)

SCIENCE WORK SHEET

Section________________ LESSON 6 Name__________________

Proceed with this lesson exactly as you did with previous lessons. (Are you making good use of the dictionary, glossary, or encyclopedia, also?)

TODAY'S BASIC SCIENCE	- A	SCIENCE IN THE SPACE AGE	- E
SCIENCE LIFE 5	- B	NEW DYNAMIC BIOLOGY	- F
SCIENCE, A WAY TO SOLVE PROBLEMS	- C	SCIENCE, A SEARCH FOR EVIDENCE	- G
SCIENCE AND YOUR FUTURE	- D	SCIENCE LIFE 6	- H

1. What is qualitative analysis? Define quality. (p. 140-C)

2. Define quantitative analysis. (p. 140-C)

3. Define hypothesis. (p. 40-C; 97-A; pp. 4-6-G; p. 48-D; pp. 4-8-H)

4. Define lever. (p. 288-B; pp. 198-199-G; p. 287-H)

5. Read pp. 115-117-E regarding building a sensitive balance. What was actually being weighed in this experiment?____________________
What were the units of weight measurements?____________________

6. How can a lever be compared to a simple balance such as you find on pp. 115-117-E? (pp. 33-37-D)

7. What advantage would a spring balance have over a simple balance? (pp. 186-187-G)

8. What are the steps or methods a scientist uses when he attempts a problem or experiment? (pp. 47-48-D; pp. 63-66-F; p. 8-B; pp. 1-22-G)

APPENDIX B

UNIT TEST

Name ______________________________

DIRECTIONS: Each question on this test is a multiple-choice question. This means that you have four choices from which to choose one best answer. Choose the letter which you think represents the best answer and put it on the line by the number of the test item. Do not hurry; you should have sufficient time to finish.

_____ 1. Which of the following is not a compound?
(a) water
(b) sugar
(c) carbon dioxide
(d) hydrogen

_____ 2. The branch of science which is concerned with the identification and classification of plants and animals is

(a) chromatography.
(b) taxonomy.
(c) chemistry.
(d) measurement.

_____ 3. The scientific name of the white oak is Quercus alba. These two words designate the

(a) phylum and class.
(b) family and species.
(c) genus and species.
(d) class and family.

_____ 4. Which of the following is a waste product when sucrose is broken down with the liberation of energy by yeasts?

(a) carbon dioxide (CO_2)
(b) sodium hydroxide ($NaOH$)
(c) hydrochloric acid (HCl)
(d) water (H_2O)

_____ 5. In classifying plants and animals, why is the practice of assigning Latin names to each organism followed?

(a) In medical practice prescriptions are written in Latin.
(b) Latin is the language of scholars--all scholars speak Latin.
(c) Latin is a simple language.
(d) Common names differ from one locality or country to the other.

_____ 6. Metabolism is

(a) cellular activity which releases energy.
(b) reproduction of a cell.
(c) exchange of materials in a cell.
(d) growth of a cell.

_____ 7. A mode is something that

(a) a sample could have but a population could never have.
(b) causes a warping factor in a distribution.
(c) is the average or typical occurrence of related happenings in nature.
(d) rarely comes close to the norm in a normal distribution.

_____ 8. Which of the following classification categories includes the remaining three?

(a) order
(b) species
(c) family
(d) genus

_____ 9. Which of the following terms includes the other three?

(a) molecule
(b) element
(c) atom
(d) compound

_____ 10. An hypothesis is

(a) a suggested activity.
(b) an intelligent guess that a scientist uses in his work.
(c) an explanation which is established as a result of research.
(d) an experiment.

_____ 11. The low power magnification achieved with compound microscopes (the ocular and low power objective) is about

(a) 10-15 times.
(b) 40-50 times.
(c) 400-500 times.
(d) 100-150 times.

_____ 12. A population consists of the set: (4, 6, 8, 10, 12, 14, 16, 18, 20). Which of the following constitutes a sample from that population?

(a) (4, 6, 8, 10, 11, 12).
(b) (14, 16, 20, 2, 4, 6).
(c) (10, 12, 14, 16, 18).
(d) (8, 12, 16, 19, 20).

_____ 13. A solvent is something that

(a) dissolves a substance in solution.
(b) is a solid substance placed in water.
(c) is separated into component parts.
(d) is always water and can be nothing else.

_____ 14. A centimeter is equal to approximately

(a) 2 inches.
(b) one-half inch.
(c) 2.54 inches.
(d) 10 inches.

_____ 15. When balancing weights on a simple balance, the number of additional items used on one side to balance the other is called a

(a) lever.
(b) fulcrum.
(c) correction factor.
(d) standard.

_____ 16. A petiole is something associated with

(a) a lima bean seed.
(b) a leaf.
(c) a unit of measurement.
(d) a paramecium.

_____ 17. A solution was placed on a piece of litmus or pH paper. The resulting color was blue. This indicates that the solution was

(a) slightly acidic.
(b) highly acidic.
(c) slightly basic.
(d) highly basic.

_____ 18. A mixture differs from a compound in that

(a) all its atoms are the same.
(b) it is made up of one kind of molecule.
(c) it is made up of more than one kind of molecule.
(d) all its atoms are different.

_____ 19. The end products of sugar fermentation are

(a) hydrochloric acid and sodium hydroxide.
(b) carbon dioxide and ethyl alcohol.
(c) carbon dioxide and sucrose.
(d) sucrose and ethyl alcohol.

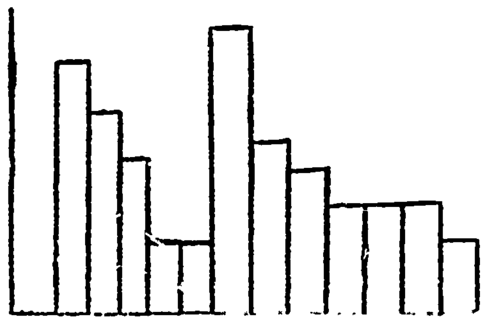
_____ 20. The gradual change from acidity to alkalinity would be an example of

(a) a bell-shaped curve.
(b) a correction factor.
(c) a warping factor.
(d) a gradient.

_____ 21. Any group of people or objects which are alike in one or more ways is called a

(a) representation.
(b) frequency distribution.
(c) population.
(d) characteristic.

_____ 22. The distribution represented by the figure at the right could be called a (an)



(a) normal distribution.
(b) warped distribution.
(c) typical distribution.
(d) even distribution.

_____ 23. Fluorine is an element consisting of a single kind of matter. Fluorine could be called a

(a) pure substance.
(b) mixture.
(c) solution.
(d) compound.

_____ 24. An object measures one-half meter in length. This means that the object is approximately

(a) a yard in length.
(b) a foot in length.
(c) 20 inches in length.
(d) a mile in length.

_____ 25. If you were told that an animal measured one micron you would know that the animal was in length

(a) 1/1000 of a millimeter.
(b) 1/1000 of a meter.
(c) 1000 times a millimeter.
(d) 1/1000 of a centimeter.

_____ 26. Atom is to element as molecule is to

(a) matter.
(b) element.
(c) water.
(d) compound.

_____ 27. A solution in a test tube was tested for its pH content. The test revealed a pH of 2. Therefore,

(a) The solution caused the litmus paper to turn blue.
(b) The solution was highly acidic.
(c) The solution was slightly acidic.
(d) The solution was highly alkaline.

_____ 28. The growth of a child from birth to adult would represent

(a) a normal curve.
(b) a mode.
(c) a gradient.
(d) a quality.

_____ 29. A normal curve develops when data

(a) "pile up" at or near the norm and decrease in frequency at greater distances on the left side of the norm.
(b) "pile up" around the norm with no events happening at either extreme of the norm.
(c) "pile up" around the norm with decreasing frequency at greater distances on the right side of the norm.
(d) "pile up" at or near the norm and decrease in frequency at greater distances on each side of the norm.

_____ 30. A man may eat a steak for dinner. In order for him to have that steak the animal had to eat plants for nourishment. Plants in turn had to have food and manufactured it from carbon dioxide and water in the presence of sunlight. This process is an example of

(a) a gradient.
(b) a warping factor.
(c) interpendence.
(d) a population.

_____ 31. In working with paper chromatography, a solution of several components was placed on a piece of filter paper and submerged in water. After an adequate length of time had passed, the solution had not separated. This can be explained by the fact that:

(a) The solution must have been a primary color and there were no mixtures of pigments to be separated.
(b) It was the wrong kind of a solution.
(c) The solvent, water, apparently was not able to dissolve the solution and allow the components to separate.
(d) The student must have accidentally moistened the filter paper all over the strip before it had a chance to separate.

_____ 32. The following would most likely operate as a warping factor in studying a representative sample:

(a) Taking a national political poll only in New York City.
(b) A class with low, average and high ability students.
(c) Leaf lengths from the population of leaves from a particular tree.
(d) An adequate sample of a bean population.

____ 33. The similarities of variation between a population of lima bean seeds and elm tree leaves show:

(a) They are closely related species.
(b) That related events in any phase of nature usually form a similar pattern resembling a bell-shaped curve.
(c) That there would be some overlapping of measurements in their lengths or widths.
(d) That there is a warping factor operating, otherwise there wouldn't be any similarities.

____ 34. If the projected image of a paramecium measured three millimeters, and the degree of magnification was 20x, the actual length of the paramecium was

(a) .15 microns.
(b) 150 microns.
(c) 200 microns.
(d) 250 microns.

____ 35. In comparing the fulcrum of a lever to a yardstick, which is used as a simple balance, and which is suspended at its midpoint, the fulcrum of the simple balance would be located at

(a) 36 inches.
(b) 1 inch.
(c) 18.5 inches.
(d) 18 inches.

____ 36. It is necessary to collect data accurately if they are to be

(a) placed in a frequency table.
(b) tallied properly.
(c) used successfully in testing hypotheses.
(d) recorded easily and quickly.

____ 37. Which of the following pairs of length measurements of leaves shows the closest relationship of species?

	One Species	Second Species
(a)	55-70 mm.	80-120 mm.
(b)	65-90 mm.	80-120 mm.
(c)	90-110 mm.	115-130 mm.
(d)	70-100 mm.	115-130 mm.

A thermos bottle was half filled with a mixture of yeast, corn syrup, and water. It was then stoppered with a cotton plug. The experimental set-up was allowed to stand for 24 hours after which it was examined and certain data recorded. Items 38, 39, and 40 are concerned with these data obtained after the 24 hours had elapsed.

____ 38. The total amount of sugar inside the flask

(a) remained the same.
(b) had decreased.
(c) had increased.
(d) decreased and then increased.

_____ 39. The atmosphere inside the flask

(a) had increased in CO_2 content.
(b) had increased in oxygen content.
(c) remained the same in composition.
(d) had increased in hydrogen content.

_____ 40. The activity within the flask was possible because

(a) the yeast inhaled oxygen from the water molecule.
(b) the yeast had stored a surplus of oxygen before being mixed.
(c) yeast may carry on fermentation without consuming oxygen.
(d) sufficient air seeped through the cotton plug.

_____ 41. The relationship between two quantities is expressed as 120 microns. This means that

(a) one quantity was a unit of measurement in microns and the other quantity a millimeter.
(b) one quantity was a unit of measurement in microns and the other quantity a microscopic object.
(c) one quantity was a unit of measurement in microns and the other quantity a small leaf.
(d) one quantity was a unit of measurement in microns and the other quantity an object which is a paramecium.

_____ 42. The difference between quality and quantity is the same as that between

(a) the length of a paramecium and the length of your classroom.
(b) the shape of a Chinese elm leaf and the shape of an American elm leaf.
(c) identifying a particular substance and identifying the amount of the substance.
(d) atom and molecule.

_____ 43. A student placed a color of ink on a piece of filter paper, submerging the end sufficiently in an <u>appropriate</u> solvent. However, after much time had elapsed, the ink showed no separation of pigments. What happened?

(a) The student must have accidentally moistened the filter paper all over the strip before it had a chance to separate.
(b) The ink was a primary color and there were no mixtures of pigments to be separated.
(c) The filter paper had pores that were too large and it could not absorb each pigment separately.
(d) It probably wasn't the proper kind of ink.

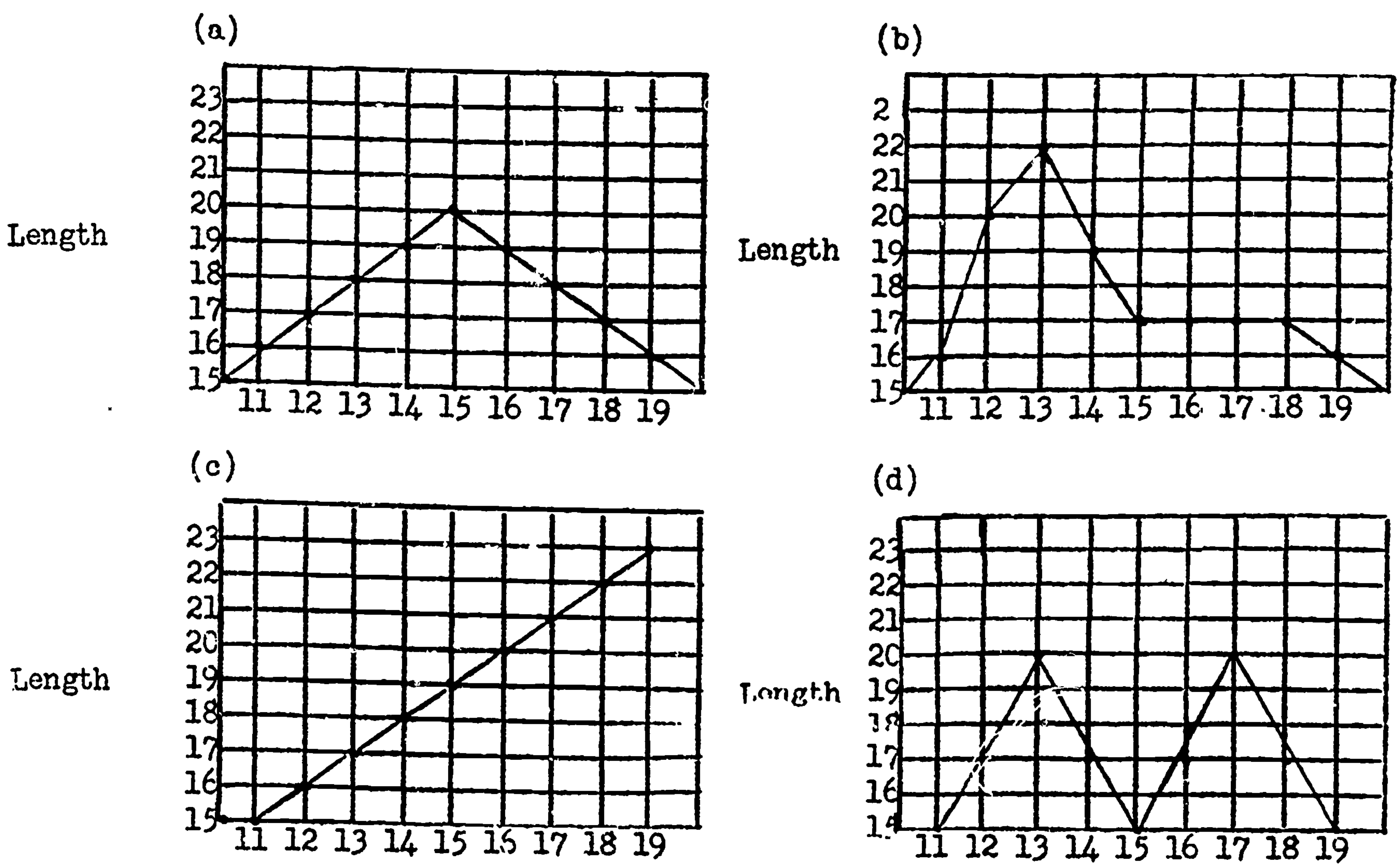
Questions 44,45,46, and 47 relate to the following table which gives the length and width of a sample of 150 lima bean seeds.

Number of Beans	Length in mm.	Width in mm.
5	15	11
10	16	12
20	17	13
25	18	14
30	19	15
25	20	16
20	21	17
10	22	18
5	23	19

_____ 44. Which of the following is the best reason for presenting the above data in a table?

(a) It points up the reason why long lima beans are wider.
(b) It is a clear way of showing relationship.
(c) It has fewer mistakes than any other way of reporting the data.
(d) It requires little intelligence to interpret it.

_____ 45. Which of the following graphs correctly expresses the data in the table?



_____ 46. On the basis of the data given, it could be reasonably predicted that an additional bean measuring 14 mm. in length would have a width

(a) closer to 11.5 mm.
(b) closer to 12 mm.
(c) closer to 20 mm.
(d) closer to 10 mm.

_____ 47. On the basis of the data given, the most typical bean length is

(a) 17.
(b) 18.
(c) 19.
(d) 20.

_____ 48. In which of the following situations do you think it would be most important to know about the 50 cents?

(a) If you have only $1.50 when you are ordering dinner at a restaurant.
(b) If you have $151.50 in the bank when you wish to buy an article of clothing.
(c) If you have $5,151.50 in a savings account and you wish to make a down payment on a house.
(d) If an intercontinental ballistic missile costs $5,151,151,151.50.

_____ 49. In establishing a simple balance using the BBs and pennies in cans balanced on a yardstick, the object was

(a) to try keeping one can of BBs balanced so the other wouldn't fall off.
(b) to show a relationship between two quantities by measurement.
(c) to set up pennies as a unit of measurement or as a standard.
(d) to demonstrate how much quarter-inches weighed in terms of pennies.

_____ 50. Suppose we have a representative sample of each of the following groups of pennies, and assume that they were of equal weight on either the "heads" or the "tails" side when they were made. Making allowances for warping factors that may have altered some of the pennies, which group do you think would most likely present the truest normal curve if the frequency of an equal number of tosses were plotted on a graph?

(a) Those made in 1955.
(b) Those made in 1939.
(c) Those made in 1964.
(d) Those made in 1950.

EVALUATION OF METHOD OF PROGRAMMING

These twelve questions are merely asked to discover how well you enjoyed using these programmed lessons. Please read the question well; then place an X in the blank by the answer of your choice. You need not sign your name.

1. Compared to regular classroom instruction how effective have the programmed materials been in teaching you science?

   _______ much better.

   _______ somewhat better.

   _______ about the same.

   _______ somewhat less.

   _______ much less.

2. Compared to regular classroom instruction how do you like the programmed instruction method?

   _______ much better.

   _______ somewhat better.

   _______ about the same.

   _______ somewhat less.

   _______ much less.

3. How difficult was it to learn about science using programmed materials as compared to using a regular textbook?

   _______ much harder.

   _______ somewhat harder.

   _______ about the same.

   _______ somewhat easier.

   _______ much easier.

4. Comparing regular classroom instruction to programmed instruction, how often do you have a chance to ask the teacher questions?

   _______ much more often with programmed instruction.

   _______ somewhat more often.

   _______ about the same.

   _______ somewhat less often with programmed instruction.

   _______ much less.

5. Do you think the programming method is a good approach to use in teaching laboratory procedures and skills?

_______ Definitely, yes.

_______ Generally, yes.

_______ Generally, no.

_______ Definitely, no.

6. Do you think simple, individual, laboratory experiments are too advanced for your grade level?

_______ Definitely, yes.

_______ Generally, yes.

_______ Generally, no.

_______ Definitely, no.

7. Do you think you learned more by actually participating in laboratory experiences that demonstrated what you were asked to study?

_______ Definitely, yes.

_______ Generally, yes.

_______ Generally, no.

_______ Definitely, no.

8. Did you find the words too difficult for your grade level in the programmed lessons?

_______ Definitely, yes.

_______ Generally, yes.

_______ Generally, no.

_______ Definitely, no.

9. After using programmed materials I like my science class

_______ much better than before.

_______ somewhat better.

_______ about the same.

_______ somewhat less than before.

_______ much less.

10. Would you like to use programmed instruction in another science class?

_______ Yes, I would like to.

_______ It does not matter either way.

_______ No, I would not like to.

11. What did you like most about this type of programmed lessons?

12. What did you like least about this type of programmed lessons?

APPENDIX C

Table 2

Indices of Item Difficulty and Proportion Choosing

Four Options for Pretest

Item Number	Item Difficulty	Option 1	Option 2	Option 3	Option 4
* 1	0.597	0.104	0.186	0.113	0.597
* 2	0.697	0.176	0.697	0.100	0.023
* 3	0.525	0.208	0.095	0.525	0.167
* 4	0.339	0.339	0.204	0.217	0.207
* 5	0.380	0.149	0.258	0.208	0.380
* 6	0.394	0.394	0.090	0.299	0.204
** 7	0.439	0.158	0.208	0.439	0.176
* 8	0.294	0.294	0.235	0.231	0.222
* 9	0.457	0.131	0.213	0.186	0.457
**10	0.683	0.086	0.683	0.195	0.036
*11	0.181	0.344	0.312	0.145	0.181
**12	0.683	0.181	0.054	0.683	0.081
*13	0.679	0.679	0.172	0.100	0.045
**14	0.471	0.113	0.471	0.285	0.127
*15	0.222	0.303	0.253	0.222	0.208
*16	0.222	0.195	0.222	0.333	0.249
*17	0.308	0.145	0.380	0.163	0.308
*18	0.493	0.100	0.136	0.493	0.267
*19	0.136	0.294	0.136	0.394	0.158
**20	0.452	0.190	0.176	0.167	0.452
**21	0.294	0.136	0.122	0.294	0.443
**22	0.557	0.109	0.557	0.231	0.095
*23	0.579	0.579	0.086	0.208	0.122
**24	0.507	0.181	0.240	0.507	0.068
*25	0.321	0.321	0.204	0.208	0.244
*26	0.380	0.475	0.090	0.068	0.380
*27	0.222	0.371	0.222	0.149	0.213
**28	0.226	0.398	0.213	0.226	0.127
**29	0.285	0.140	0.199	0.290	0.285
**30	0.448	0.222	0.181	0.448	0.127

*Factual-oriented items
**Conceptual-oriented items

Table 2

(Continued)

Item Number	Item Difficulty	Option 1	Option 2	Option 3	Option 4
**31	0.367	0.244	0.158	0.367	0.149
**32	0.195	0.195	0.371	0.208	0.176
**33	0.190	0.321	0.190	0.231	0.226
**34	0.244	0.294	0.244	0.249	0.181
*35	0.430	0.217	0.113	0.199	0.430
**36	0.403	0.158	0.222	0.403	0.199
**37	0.299	0.167	0.299	0.385	0.113
**38	0.271	0.321	0.271	0.208	0.158
**39	0.253	0.253	0.231	0.267	0.204
**40	0.267	0.231	0.267	0.267	0.204
**41	0.208	0.285	0.208	0.244	0.204
**42	0.502	0.131	0.140	0.502	0.204
**43	0.475	0.140	0.475	0.240	0.100
**44	0.475	0.158	0.475	0.163	0.181
**45	0.412	0.199	0.199	0.412	0.167
**46	0.362	0.163	0.181	0.249	0.362
**47	0.308	0.235	0.186	0.308	0.226
**48	0.480	0.480	0.136	0.145	0.204
**49	0.475	0.167	0.475	0.208	0.109
**50	0.457	0.122	0.217	0.457	0.167

*Factual-oriented items
**Conceptual-oriented items

Table 3

Indices of Item Difficulty and Proportion Choosing

Four Options for Posttest

Item Number	Item Difficulty	Option 1	Option 2	Option 3	Option 4
* 1	0.656	0.131	0.118	0.090	0.656
* 2	0.864	0.113	0.864	0.018	0.005
* 3	0.643	0.140	0.122	0.643	0.095
* 4	0.561	0.561	0.149	0.158	0.127
* 5	0.443	0.136	0.258	0.158	0.443
* 6	0.452	0.452	0.231	0.176	0.136
**7	0.593	0.050	0.240	0.593	0.104
* 8	0.538	0.538	0.136	0.249	0.077
* 9	0.588	0.140	0.208	0.100	0.588
**10	0.810	0.045	0.810	0.118	0.027
*11	0.276	0.489	0.167	0.068	0.272
**12	0.860	0.072	0.041	0.860	0.027
*13	0.814	0.814	0.059	0.068	0.059
**14	0.380	0.068	0.380	0.489	0.054
*15	0.697	0.145	0.063	0.697	0.095
*16	0.557	0.136	0.557	0.167	0.136
*17	0.385	0.095	0.344	0.172	0.385
*18	0.529	0.086	0.122	0.529	0.262
*19	0.471	0.090	0.471	0.244	0.190
**20	0.561	0.303	0.027	0.109	0.561
**21	0.661	0.059	0.086	0.661	0.185
**22	0.787	0.104	0.787	0.081	0.023
*23	0.769	0.769	0.068	0.100	0.054
**24	0.615	0.154	0.186	0.615	0.036
*25	0.534	0.534	0.186	0.154	0.122
*26	0.421	0.407	0.113	0.054	0.421
*27	0.312	0.213	0.312	0.299	0.172
**28	0.579	0.258	0.140	0.579	0.059
**29	0.548	0.131	0.190	0.127	0.548
**30	0.647	0.149	0.104	0.647	0.100

*Factual-oriented items
**Conceptual-oriented items

Table 3

(Continued)

Item Number	Item Difficulty	Option 1	Option 2	Option 3	Option 4
**31	0.353	0.385	0.063	0.353	0.199
**32	0.281	0.281	0.376	0.204	0.136
**33	0.443	0.145	0.443	0.249	0.145
**34	0.371	0.235	0.371	0.262	0.127
*35	0.715	0.122	0.072	0.086	0.715
**36	0.407	0.244	0.217	0.407	0.127
**37	0.367	0.145	0.367	0.425	0.063
**38	0.348	0.199	0.348	0.326	0.127
**39	0.498	0.498	0.213	0.109	0.176
**40	0.466	0.258	0.127	0.466	0.149
**41	0.362	0.312	0.362	0.122	0.190
**42	0.475	0.167	0.217	0.475	0.140
**43	0.557	0.199	0.557	0.140	0.104
**44	0.552	0.127	0.552	0.154	0.167
**45	0.462	0.204	0.253	0.462	0.077
**46	0.475	0.131	0.208	0.186	0.475
**47	0.480	0.113	0.136	0.480	0.271
**48	0.566	0.566	0.086	0.085	0.253
**49	0.575	0.090	0.575	0.195	0.140
**50	0.624	0.100	0.181	0.624	0.095

*Factual-oriented items
**Conceptual-oriented items

Table 4

Indices of Item Difficulty, Item Standard Deviation, and Item-Total Correlation for Pretest

Item Number	Item Difficulty	Standard Deviation	Item-Total Correlation
* 1	0.597	0.490	0.204**
* 2	0.697	0.460	0.460**
* 3	0.525	0.499	0.338**
* 4	0.339	0.473	0.212**
* 5	0.380	0.485	0.330**
* 6	0.394	0.480	0.215**
** 7	0.439	0.496	0.159*
* 8	0.294	0.456	0.286**
* 9	0.457	0.498	0.395**
**10	0.683	0.465	0.370**
*11	0.181	0.385	-0.027
**12	0.683	0.465	0.281**
*13	0.679	0.467	0.392**
**14	0.471	0.499	0.168*
*15	0.222	0.415	0.141*
*16	0.222	0.415	0.282**
*17	0.308	0.462	0.278**
*18	0.493	0.500	0.224**
*19	0.136	0.343	0.004
**20	0.452	0.498	0.267**
**21	0.294	0.456	0.266**
**22	0.557	0.497	0.382**
*23	0.579	0.494	0.510**
**24	0.507	0.500	0.436**
*25	0.321	0.467	0.321**
*26	0.380	0.485	0.345**
*27	0.222	0.415	0.038
**28	0.226	0.418	0.166*
**29	0.285	0.451	0.264**
**30	0.448	0.497	0.406**

*Significant at .05 level
**Significant at .01 level

Table 4

(Continued)

Item Number	Item Difficulty	Standard Deviation	Item-Total Correlation
**31	0.376	0.482	0.255**
**32	0.195	0.396	0.069
**33	0.190	0.392	0.078
**34	0.244	0.430	-0.056
*35	0.430	0.495	0.308**
**36	0.403	0.490	0.126
**37	0.299	0.458	0.197**
**38	0.271	0.444	0.130
**39	0.253	0.435	0.145*
**40	0.267	0.442	0.154**
**41	0.208	0.406	0.147*
**42	0.502	0.500	0.360**
**43	0.475	0.499	0.217**
**44	0.475	0.499	0.358**
**45	0.412	0.492	0.308**
**46	0.362	0.481	0.354**
**47	0.308	0.462	0.258**
**48	0.480	0.500	0.213**
**49	0.475	0.499	0.390**
**50	0.457	0.498	0.218**

*Significant at .05 level
**Significant at .01 level

Table 5

Indices of Item Difficulty, Item Standard Deviation,

and Item-Total Correlation for Posttest

Item Number	Item Difficulty	Standard Deviation	Item-Total Correlation
1	0.656	0.475	0.384**
2	0.864	0.343	0.326**
3	0.643	0.479	0.350**
4	0.561	0.494	0.493**
5	0.443	0.497	0.402**
6	0.452	0.498	0.264**
7	0.593	0.491	0.406**
8	0.538	0.499	0.311**
9	0.588	0.492	0.384**
10	0.810	0.392	0.308**
11	0.276	0.447	0.040
12	0.860	0.347	0.347**
13	0.814	0.389	0.379**
14	0.380	0.485	0.097
15	0.697	0.460	0.459**
16	0.557	0.497	0.320**
17	0.385	0.487	0.281**
18	0.529	0.499	0.208**
19	0.471	0.499	0.310**
20	0.561	0.496	0.490**
21	0.661	0.473	0.321**
22	0.787	0.409	0.306**
23	0.769	0.421	0.472**
24	0.615	0.487	0.389**
25	0.534	0.499	0.343**
26	0.421	0.494	0.419**
27	0.312	0.464	0.193**
28	0.579	0.494	0.359**
29	0.548	0.498	0.378**
30	0.647	0.478	0.379**

*Significant at .05 level
**Significant at .01 level

Table 5

(Continued)

Item Number	Item Difficulty	Standard Deviation	Item-Total Correlation
31	0.353	0.478	0.146*
32	0.281	0.449	0.392**
33	0.443	0.497	0.281**
34	0.371	0.483	0.071
35	0.715	0.451	0.401**
36	0.407	0.491	0.272**
37	0.367	0.482	0.261**
38	0.348	0.476	0.271**
39	0.498	0.500	0.388**
40	0.466	0.499	0.278**
41	0.362	0.481	0.293**
42	0.475	0.499	0.530**
43	0.557	0.497	0.321**
44	0.552	0.497	0.284**
45	0.462	0.499	0.356**
46	0.475	0.499	0.444**
47	0.480	0.500	0.522**
48	0.566	0.496	0.306**
49	0.575	0.486	0.286**
50	0.624	0.484	0.339**
			**

*Significant at .05 level
**Significant at .01 level

Table 8

Correlation Matrix for Programmed Lessons

Lesson Variable	2	3	4	5	6
1	0.8136	0.8333	0.8057	0.8153	0.8330
2		0.8683	0.8673	0.8788	0.8826
3			0.9149	0.9052	0.8901
4				0.8866	0.8911
5					0.9437
6					——

APPENDIX D

EXPERIMENTAL SCHEDULE

June, 1965 - December, 1965

Writing of the programmed instructional materials.

September, 1965 - December, 1965

Individual student pilot studies for purpose of revision of programmed instructional materials.

November 16, 1965

Interview and briefing session with principal of Pattie Hilsman Junior High School, in preparation for the final field trial.

November 17, 1965

Planning meeting with principal and seventh-grade teacher of Pattie Hilsman Junior High School.

November 21, 1965

Interview and briefing session with principal of Clarke County Junior High School, in preparation for the formal experimental study.

November 30, 1965

Orientation meeting with principal and the two participating teachers at Clarke County Junior High School.

December 9, 1965

Planning meeting with principal and two teachers at Clarke County Junior High School.

December 29, 1965

Further orientation and planning meeting with two teachers at Clarke County Junior High School.

January 3, 1966

Final field trial of programmed instructional materials was begun.
Pretest administered to experimental and control groups.

January 20, 1966

Planning session with two teachers at Clarke County Junior High School.

January 25, 1966

Planning session with two teachers at Clarke County Junior High School.

January 26, 1966

End of final field trial.
Posttest administered to experimental and control groups.
Evaluation questionnaire administered to experimental group.

January 28, 1966

Orientation of experimental and control groups of formal experimentation.
Pretest administered to experimental and control subjects at Clarke County Junior High School.

February 1, 1966

Kuder General Interest Survey (Form E) administered to control and experimental groups.

February 2, 1966

Experimental groups began the programmed, open-ended, laboratory sequence.
Control groups began the non-programmed instructional curriculum.

February 23, 1966

Kuder General Interest Survey (Form E) administered to control and experimental groups.

February 24, 1966

Evaluative questionnaire administered to experimental groups.

February 25, 1966

Posttest administered to experimental and control groups.
End of experimental period.

STUDENT COMMENTS AND REACTIONS

The following are comments and reactions of the students to questions 11 and 12 from the Evaluation Questionnaire. The questions are restated below. Among the students' comments, some of the most glaring grammatical errors have been corrected and quotation marks have been omitted.

Question 11

What did you like most about this type of programmed lessons?

1. I liked being able to conduct our experiments ourselves. Being able to work as fast as we wanted to.

2. I liked doing experiments and working with others.

3. I can go at my own speed, and I go slow.

4. You get experience in doing things yourself, learning to follow instructions, learning to work with lab procedure and lab tools. You find things more interesting and want to explore them deeper.

5. Being on your own. Reading the instruction step by step and doing what it says to do.

6. I got to ask more questions and we learned to use the microscope. We didn't have the teacher telling us what to do; all we had to do was read carefully.

7. The instructions were explained very easily.

8. You were able to work at your own rate of speed.

9. It explained things much more clearly and gave some experience in things otherwise missed.

10. That I was able to do the experiments myself, and at my own rate. Also I can go back and look over the material.

11. You could work at your own speed and you had to figure out how to do the experiments using the directions given without having someone stand over you and tell you every

movement to make.

12. If you were absent you could begin where you left off and you were not lost. You did the experiments by yourself, therefore you could understand them better.

13. When I felt like I had to ask a question I would just read the next one or two frames and there would be the answer. The experiments answered a lot of questions.

14. It doesn't get boring and I personally hate to watch a teacher do an experiment. I get more meaning from it than when the teacher does it.

15. Doing the experiments by yourself. It was organized.

16. Well, you are on your own and it's a little easier, too.

17. The freedom. I could work at my speed of time. The laboratory work made things so clear. You could feel free to ask questions. I like the type of test because there was no spelling.

18. You did what you did by yourself which helped you to remember it, and you were free to work at your own speed.

19. It was easier to read and to understand. It was fun and helpful.

20. The experiment and the way they explain how to do them.

<u>Question 12</u>

What did you like least about this type of programmed lessons?

1. Teaching ourselves by doing the experiment ourselves.

2. Answering the questions.

3. Nothing, I liked it all.

4. Having to make a lot of graphs.

5. I did not learn as much from it. I feel as I won't remember things such as norms, bell-shaped curves, frequency distributions, etc., for later use.

6. I didn't dislike anything about this programmed material.

7. There was too much measuring to do.

8. There was alot of detailed work.

9. Some of the questions seem useless.

10. I think I would have understood a little better if the teacher could have talked to us more about the lessons.

11. I liked working at my own speed, but I didn't have enough time to finish.

12. Some of the material used was misplaced or lost if we did not finish the work in one day.

13. Not really anything. I enjoyed it very much.

14. The frames repeat themselves too often to suit me.

15. I liked it all.

16. Well, I didn't like all those questions even though they were important.

17. Well, at the end, it was so much to look over for the test. But that was all.

18. Too many questions to answer.

19. Answers on the side.

20. I was bored.